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**EUROPEAN SCIENTIFIC NOTES  
OFFICE OF NAVAL RESEARCH  
LONDON**

edited by Donald R. Barr and Don J. Peters  
30 September 1982      Volume 36, No. 9

**AEROSPACE**

→ Solid Propellants and Explosives: -

This is a report on an international meeting on solid propellants and explosives held in Karlsruhe, Germany. Among topics discussed were plastic bonded explosives, low-vulnerability ammunition, and ignition behavior of solid propellants when subjected to low flux levels and subatmospheric environments.

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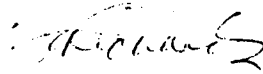
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Chief Scientist



L.B. Sykes  
Captain, USN  
Commanding Officer

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Dr. D.R. Barr  
Dr. J.F. Blackburn  
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Electronics



## SOLID PROPELLANTS AND EXPLOSIVES

The Thirteenth Annual Conference of the Fraunhofer Institute for Propellants and Explosives (ICT) was held in Karlsruhe, Germany from 29 June to 1 July 1982. The title for this year's meeting was, "Use of Plastic Materials for Propellants and Explosives."

The ICT, one of 25 research institutes within the Fraunhofer-Gesellschaft, contracts with private industry and government agencies for research and development projects in the fields of solid propellants and explosives and the application of such materials in solid propellant rocket motors, guns, and high explosives. Each year ICT sponsors an international conference dealing with a narrow topic area within these somewhat broad interests. This year's conference provided an excellent forum for both solid propellant and explosive specialists to meet and interact. Papers presented were relevant to an area that, at present, is receiving considerable attention in the US: the development of improved insensitive energetic materials for low weapon vulnerability. The subject embraces technical expertise in chemical and mechanical processing techniques, performance measurements, ignitions, combustion, and detonics of energetic materials.

The annual ICT conferences have gained an excellent reputation among international scientists because of the outstanding efforts of the host, Dr. Hiltmar Schubert, director of ICT, and his staff. In general, the conferences are highly professional and well organized; simultaneous translations are provided in English, French, and German. This year's meeting attracted about 300 scientists from 20 countries (including Israel, Japan, Thailand, and Turkey) with papers presented by authors from 10 different countries (including Egypt, The People's Republic of China, and the Republic of South Africa). Approximately one-third of the papers were by US authors. The following are highlights from selected topics and papers. The complete agenda has been published as ONRL Military Applications Summary - Bulletin No. M89-82, which can be obtained from ONRL by request.

Dr. J. Kincaid (Johns Hopkins Univ.) discussed "The Determination of the Propensity for Detonation of High Energy Propellants." He reviewed the basic parameters that can be used to determine the propensity of any given solid propellant to undergo inadvertent detonation. In addition to deflagration-to-detonation-transition (DDT) and shock-to-detonation-transition (SDT) behavior, Kincaid discussed a new phenomenon known as XDT, so named because of its puzzling behavior. It is a shock-to-detonation characterized by reduced

shock energy input required for initiation and by increased delay from shock arrival to transition to detonation. As a result of recent studies, much has been learned about detonation risk in solid rocket motors. In spite of the advances, however, the paper emphasized the need for additional studies of the controlling mechanisms and physical variables associated with DDT and XDT in high-energy solid propellants.

The US Navy's programs for the development of plastic bonded explosives (PBX) were outlined in two papers. In the first, Dr. L. Rothstein (Naval Weapons Station, Yorktown, VA) discussed the broad subject of "Plastic Bonded Explosives - Past, Present, and Future." In his talk, the US Navy's explosive binder research program (sponsored by Dr. R. Miller, Office of Naval Research) was reviewed. The goal of the program is to create energetic analogues of both hydroxyl-terminated (polybutadiene) and polyether prepolymers. The new prepolymers and resultant polymers will have improved physical properties as well as higher explosive yields. The program, a combined effort of university, private industry, and government laboratory expertise, is concerned with five energetic prepolymer types: (1) polynitro formals, (2) linear nitramine polymers, (3) nitrodiene polymers, (4) nitro and diazide oxetanes, and (5) glycidylazide polymers (GAP) based on polyepichlorohydrin. In the second paper, Mr. Max Stosz (Naval Surface Weapons Center, White Oak, MD) discussed "The Development of New Explosives for the US Navy." PBX compositions were divided into families related to their application (e.g., underwater and reduced vulnerability to fragment attack) and their development and use in warheads. Work in the US was described in terms of the Navy Explosives Advanced Development (EAD) Program. The EAD program addresses the need for meaningful predictive and experimental approaches to assess the performance and vulnerability of new high explosives used in US Navy Ordnance. In the past, it has been noted that results from large-scale tests, which are expensive and time consuming, differ from those of relatively low cost laboratory tests. Accordingly, the program can provide extremely important information relevant to the development of new PBXs and, perhaps, high-energy solid propellants.

Five papers were presented on the general subject of low-vulnerability ammunition (LOVA) for guns. In addition to three that covered the US efforts, an ICT paper, "Nitramine Powders: Theoretical and Applied Studies for LOVA," and a French paper, "Desensitization of Propulsive Charges in Tank Munitions," were presented. The French paper, by Dr. R. Mesnit (Establishment for the Study and Manufacture of Armaments at Bourges) described an interesting method for reducing the vulnerability of propulsive munitions to hollow charges. In this approach, the loose

multiperforated cylinders of propellant that constitute a gun's propulsive charge are fixed in place by curing a slurry of fine granulated propellant and binder. Results from tests using 105-mm munitions show that the ballistic properties for the desensitized propulsive charge are not markedly different from those of the loose bed charges. Yet the vulnerability of the desensitized material to a shaped charge is significantly reduced.

Dr. A. Iwama (Institute of Space and Astronautical Science, Tokyo, Japan) presented results from an ignition study of composite solid papers. Iwama is interested in the ignition behavior of solid propellants when they are subjected to low flux levels and subatmospheric environments. The practical application of results was reported to be related to the design of igniters for upper stage rocket motors. Iwama also noted the possibility of using an Earth-based laser for ignition of solid propellants located in space. In any event, the test data he presented are unique because of the low pressures and heat flux levels he has considered. The propellant was a simple polybutadiene/ammonium perchlorate formulation. Small samples were exposed to low radiant energy levels (up to 5 cal/cm<sup>2</sup> sec) in a nitrogen atmosphere. Three different subatmospheric pressures were considered: 30, 50, and 100 torr. Test results showed four modes of ignition behavior at these low pressures: (1) no ignition - no flame, (2) self-sustaining ignition - stable combustion, (3) nonsustaining ignition - extinguishment if the radiation source is removed, and (4) pulsating ignition. It was noted that the nonsustaining ignition mode existed when the pressure was minimized and the heat flux maximized. Overall results in the paper describe the importance of the energy balance at and beneath the propellant surface. Although Iwama's work is being conducted for the design of igniters, it appears his results are also relevant to the extinguishment and inadvertent reignition of solid rocket motors used in conjunction with dual chamber controllable rocket motors.

In a second paper by a Japanese, Dr. Saito (Inst. of Space and Astronautical Sciences, Tokyo) presented preliminary results from a study of surface temperature measurements of a composite propellant ignited at subatmospheric pressure. An infrared detector was used to scan a propellant surface heated by a CO<sub>2</sub> laser beam. The goal was to map the temperatures across the propellant surface. Problems that have prevented meaningful results from being obtained include lack of optical uniformity across the propellant surface and inadequate sensitivity of the infrared detectors. Although results from this paper and the companion paper by Iwama are inconclusive, valuable information concerning laser experimentation is given. Since the laser is becoming increasingly popular for studies of solid propellant ignition, these papers could

prove useful for development of laser experiments.

A paper entitled "The Effect of HTPB Polymer Characteristics on Propellant Performance" was presented by Dr. D. Fukuma of the Institute of Space and Astronautical Science, Tokyo, Japan. Fukuma described the effects of changes in prepolymer on the mechanical properties of hydroxyl-terminated polybutadiene (HTPB) composite solid propellants. The influence of the polymer microstructure, molecular weight distribution, viscosity, and functional properties were discussed. For the study, the authors developed a new polymerization process for HTPB and compared the characteristics of the new prepolymer, K-31, with those of R-45M and R-45HT produced by ARCO. Results showed that the mechanical properties of a solid propellant are closely related to the HTPB polymer characteristics. In addition, it appears that the prepolymer developed by Japan is competitive with ARCO prepolymers from the US.

Dr. Hadhoud (Military Technical College, Cairo, Egypt) presented a paper entitled "Rheological and Explosive Properties of Plastic Bonded High Explosives Based on HTPB." The work illustrated the effect of variations in formulating parameters and processing conditions on the rheological behavior of uncured plastic-bonded high-explosive composites. Formulating parameters included the variation of type and content of both the crosslinkers and the chain extenders, variation of high explosive content, type, state, and plasticizers.

The subject of "Sensitiveness and Explosiveness of Plastic Bonded Explosives" was presented by Mr. J. Connors (Royal Armament Research and Development Establishment [RARDE], UK). The concept of sensitiveness and explosiveness has been promoted in the UK in the past. It is appealing because it logically separates the ease of an explosive to initiate (sensitiveness) from its explosive output (explosiveness). Connors presented results from small-scale tests designed to measure the two parameters for various plastic-bonded explosives developed at RARDE.

Three papers related to the cook-off or thermal explosion characteristics of solid propellants were presented. In one Dr. Hans Pasman (Prins Maurits Laboratory - TNO, the Netherlands) presented "An Investigation into the Sensitivity of Plastic-Bonded Explosives by Means of the Thermal Step Test." In the test a sample of explosive is confined in a stainless steel tube, which is heated to a temperature of 1400°K in about 30 microseconds. The induction time - time to explosion - as a function of temperature yields information about the kinetics of the thermal decomposition process. This experimental approach is being developed by Pasman and co-workers and shows promise for quantitative determination of sensitiveness.

At the close of the meeting, audience attendance was not noticeably different from the first day. It would seem that a meeting designed for specialists in high-explosive and solid propellants is of interest to both communities. Because the energy level of solid propellants in rocket motors continues to increase, this is not surprising. Such meetings, however, are not held often enough and, unfortunately, the 1983 ICT Meeting will not address the same subject. The Thirteenth ICT Meeting, therefore, was unusual. For those specialists interested in both high explosives and solid propellants, the proceedings will prove to be quite valuable.

*R.L. Derr*

ONR London

## BEHAVIORAL SCIENCES

### A DECISION AID FOR CLASSIFYING PATTERNS

Sometimes the classification of visual patterns can be accomplished by statistical algorithms. An example is the linear discriminant approach, which operates on a multivariate feature vector for each pattern. If all the patterns are linearly separable into discrete classes according to features, weights can be calculated for an optimal classification procedure. Once all the features and class membership thresholds are known, human input to the classifying system is essentially clerical. Such methods are quite useful and are surprisingly robust over violations of linearity and equal-covariance assumptions.

It often happens, though, that currently available statistical procedures cannot be applied to the classification problem. In some cases, the features cannot be specified precisely enough for an algorithmic scheme; in others, the criteria for class inclusion are nonstationary or differ among individuals; in still others, the number of classes changes according to the data-quality circumstances prevailing at a particular time. The extremely difficult job of classifying cytological tissue samples for medical purposes is an example. Even in such complex situations, a decision aid may help the human classifier. An interesting system was recently described by K.F. Kraiss (Forschungsinstitut für Anthropotechnik, Wernhoven, West Germany). His system resembles those proposed by Amos Freedy (Perceptronics, Inc., Woodland Hills, CA) and others, with perhaps an unusual feature or two. Kraiss has done preliminary runs of the system on realistic signal patterns, and his evaluation points up some of the methodological issues that arise in the development of interactive decision aids.

Kraiss used a set of 50 visual patterns; each pattern was composed of 20 columns of dots and each column could have from 2 to 8 dots. Some of the patterns were multimodal, some were unimodal, some were rather flat. Many of the patterns superficially resembled real signals such as intensity-frequency sonar plots. Kraiss also had a set of 6 standard or reference patterns; the classifier's task was to assign each of the 50 test patterns to one of the 6 classes. (The six reference patterns were always available to the human subjects.) The assignment task was quite difficult for some of the patterns; in fact, a "confusion matrix" tabulation showed that identical choices across subjects could be expected for only a few patterns. This meant that individual, and possibly shifting, criteria were being used by the human classifiers.

Suppose that several people have sorted all the signals into the six classes. Kraiss devised a computer program that learned the criteria being used by each individual and furnished continual information regarding the individuals' consistency of choices. The learning machine operated in three modes, a stepwise mode and two retrospective learning modes. When running in stepwise mode, the machine began with the weight for each column vector set at zero. Assume a first test pattern is fed to the machine and is assigned by the human classifier to a category, say category C. The machine notes this, evaluates each of the 20 columns in the pattern, and weights the columns for C. If the pattern is unimodal the weights for column 1 and column 20 probably will be relatively low and the weights toward the center columns will be high. The process continues as more patterns are fed to the human classifier and to the machine. If a pattern has been called C, an adjustment is made to the weights when the calculation indicates that it corresponds better to a D class. Eventually the weights can be expected to stabilize. A more elaborate computerized correction approach is to use information from previous classifications when adjusting the weights; the retrospective learning modes did exactly that. One of the modes went back to the last 10 patterns classified; the other went back over the whole set of previously classified patterns. In simulator runs, Kraiss found that stepwise learning by the machine was much slower than retrospective learning. After 150 training steps, there were still many corrections necessary for the stepwise system, whereas the retrospective learning mode was fairly well stabilized.

As noted above, one criterion used by the machine in aiding a human classifier is the consistency of his choices. Even though the (psychological) feature weights may be vague and nonstationary, they do exist, and perhaps the main value of an aiding machine is to point out and explicate inconsistencies in the way the human is sorting the material.

What happens when such a system is used with human operators? Kraiss tested it with a

small sample of 12 subjects, each of whom had to make 300 individual decisions. At each choice point, the aiding display presented information such as the following:

PROPOSED CLASS NO.: I (45 %), V (27 %)  
RELIABILITY : 60 %  
PLEASE TYPE IN THE SELECTED CLASS NO.:

Each succeeding presentation then updated the previous classifying experience. The example above shows that categories I and V are the most probable classes for this particular stimulus, based on previous learning by the machine of the human responses. The reliability number shows how often aiding was accepted by the particular human operator.

When the operator appears inconsistent to the machine, for example, when he has placed a certain pattern in both Class I and Class VI, the machine recognizes this and prints out a query, as follows:

PLEASE CONFIRM YOUR CHOICE: I or VI?

Conflicting answers made earlier can be eliminated from the final choice information.

Such aiding should reduce inconsistency over a long series of decisions, and indeed it does. Figure 1 shows that, while both unaided and aided subjects improve with practice, the aiding eventually leads to near-perfect consistency of choices for each individual. (There is some evidence that the operators can learn to discriminate between good aiding and misleading aiding.) While unaided judges might eventually perform equally well, thousands of trials might be required before they could do so.

The Werthoven system is not intended to replace the human operator, nor does it try to tell him which classification criteria he should use. Rather, it focuses attention on the stability of certain choice behaviors and thus prods the human into setting up a reliable cognitive structure for handling difficult decisions and for resolving conflicts.

It is easy to think of extensions of the Werthoven approach. At a practical level, say in military signal analysis, there is a question about what quantitative consistencies should be sought or expected. What is to be done when the training machine forces people into consistency of choice, even though they may remain uneasy about their choices? Is an operator, having achieved technical consistency, less likely to effect a radical re-ordering of the material and thus more prone to functional fixedness on the structure of the present situation? From a research standpoint, we need data over a range of classification tasks, so that we can predict which ones are most susceptible to aiding. For certain important tasks, such as those encountered in military and medical interpretations, several people may be analyzing the same materials. And, as the Kraiss data show, practiced people or experts will disagree. If they do disagree,

should the classifications of the more consistent judges be given a higher weight? Such questions will be difficult to answer, but in the aiding-system context they may become more definite and hence more tractable.

Eventually, advances in decision-theory methods for handling intra-subject and inter-subject "incoherence" may be designed into aiding machines like the Werthoven one. Judgments are incoherent when radically different values, classes, or outcome numbers are assigned by reasonable people to the same problem. The numbers may actually be so different that some sort of reconciliation seems necessary. The explorations of R.V. Brown and

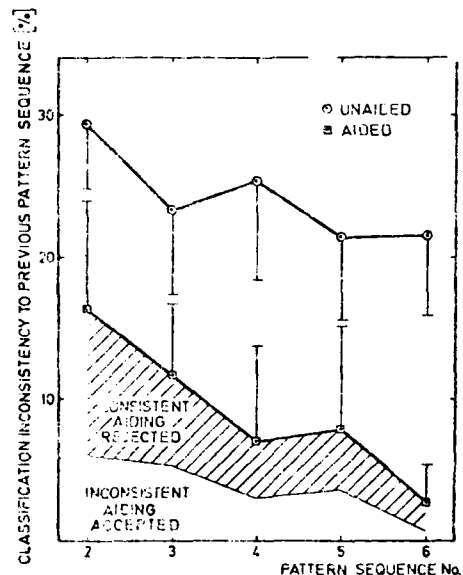


Fig. 1 Individual classification consistency with and without aiding (data from two groups of 6 subjects)

D.V. Lindley (Decision Science Consortium, Falls Church, VA) have shown several directions in which reconciliation work can proceed; for instance, judges can attempt further meta-cognitive "digging" into their own judgment processes. Another possibility is for human subjects to investigate how certain cognitive modifications in decision criteria might facilitate coherence, and then to attempt some gingerly adjustments of previous psychological structures. Under at least some conditions, the two-stage Bayesian reconciliation paradigm proposed by Brown and Lindley may be practical. There are enough intriguing problems here to engage both psychologists and statisticians for some time.

N.A. Bond, Jr.

ONR London

## CAMBRIDGE COLOR VISION MEETING

A week-long meeting on color vision, sponsored by the Human Factors Committee of NATO, was held at Cambridge University, England, in July 1982. With 200 registrants and nearly 60 papers and invited lectures, the conference probably touched on most of the active research areas. Complete proceedings will be published later this year; information may be obtained from J.D. Mollon, Department of Experimental Psychology, Cambridge University, (UK).

Psychologists should be especially interested in an "apparent motion" technique for judging equiluminance of colors on a video display. The method was described by S. Anstis (York Univ. Downsview, Canada) and P. Cavanagh (Univ. of Montreal). It is based on the fact that when a grating of red and green stripes is replaced by a similarly striped grating of dark yellow-light yellow bars displaced one quarter cycle to the right, the red-green grating appears to jump to the left if the red bars are brighter than the green bars. If the green bars are brighter, the display seems to move to the right. If red and green are of equal luminance, no apparent motion is seen.

When the striped display is computer driven on a regular four-stroke cycle, it produces perceptually continuous motion or smooth streaming of the stripes to the left or right, according to whether red or green is brighter. To judge equiluminance, the subject merely has to watch for the apparent motion to begin and to end. Experiments showed that subjects could produce luminance curves that were nearly identical to those obtained by the laborious Boynton flicker-judgment technique. Indeed, indifference variances were small at all luminances for the apparent motion method, whereas flicker ranges are noticeably larger at the lowest luminance levels. To at least one casual observer, the display at equiluminance causes a vague but interesting sense of disquiet; "something is happening," but it is not quite definite. When the luminance disparity becomes large enough to produce movement, a small sense of relief may be felt.

Several speakers dealt with video displays in color vision research. W. B. Cowan (National Research Council of Ottawa, Canada) spoke of the tradeoffs one must make when dealing with the artifacts produced by discretization of color signals. He also noted the high costs (on the order of 50K US dollars) involved for sophisticated stimulus systems. R.W. Rodieck (Univ. of Washington, US) described his stimulator setup for work with single neurons.

Spectacular work with surgically removed human eyes was reported by H.J.A. Dartnall (Univ. of Sussex), J.K. Bowmaker (Univ. of

London), and J.D. Mollon (Cambridge Univ.). Seven eyes removed because of malignancies have been studied. One eye had been removed under operating-room red light, in two cases the eyelids had been sewn together prior to removal of the eye, and in the other four cases the surgery had been done under bright lights (As it turned out, useful measurements could be made from all the material.) Following surgery, the eyes had been transferred immediately to a spectrographic unit. When the retinal material was studied for spectral response, the outer rods were grossly discriminable and had a maximum sensitivity at 496.3 nm. Outer segments of cones were not discriminable into red, green, and blue classes on gross anatomical grounds. However, over half of them peaked in the 550-570 nm zone and were designated reds; greens had peaks around 531 nm; and blues peaked at 419 nm. A surprising amount of variation was noted among the eyes, suggesting genuine individual differences in the frequencies of maximum sensitivity. The investigators had more recently tested another eye obtained surgically from a deuteranopic person; of the 17 receptors, studied, 10 were in the red-cone zone and none was within the usual green band.

Color-mechanism data relating to cats and monkeys were presented by several investigators. M. Wemrich and E. Zrenner (Max-Planck Institute, Bad Nauheim, West Germany) found three phototopically active receptor mechanisms in the cat and also hypothesized that the small numbers and reduced capability of color-opponent cells could explain the cat's inadequacy of color discrimination. J.K. Bowmaker (Univ. of London), J.D. Mollon (Univ. of Cambridge), and G.H. Jacobs (Univ. of California) gave microspectrophotometric evidence indicating that there are at least five types of color vision in the squirrel monkey.

B.W. van Dijk and H. Spekrijse (Univ. of Amsterdam, Netherlands) investigated the interactions in carp ganglion cell responses. Part of the work involved the application of ethambutol, a tuberculostatic drug that causes color vision deficiencies in man. Ethambutol decreased the color opponent mechanism in the carp material but did not affect the sensitivity of the spectral mechanisms involved.

E. Wolf and H. Scheibner (Univ. of Dusseldorf, West Germany) sought to determine the exact tritanopic copunctal point for blue on the standard chromaticity chart. They reasoned that the point would have to be in the plane in color space that has no luminance information; also, it should lie on the alychne of protanopic and deuteranopic observers, since the blue-cone features for such people are the same as for normals. From data on normals, protanopes, and deuteranopes, they found that the alychne traces intersected almost exactly in the same point ( $x=0.1506$  and  $y=0$ ).

At the University of Munich, West Germany, R. Hiltz, M. Baie, and I. Rentschler studied the responses of three subjects with

strabismic amblyopia to wavelength discrimination in isoluminant gratings. The subjects had impaired contrast sensitivity in their amblyopic eye, but the color difference sensitivity in the amblyopic eye was the same as in the good eye. The Munich researchers interpreted this as another indication that color and pattern vision are functionally independent processes.

It is frequently cited that color differences themselves, without luminance differences, do not accentuate stereopsis in random-dot Julesz stereograms. What happens, however, if the stimulus object to be seen in depth is figural or is detectable monocularly? C.M.M. DeWeert and K.J. Sadza (Catholic Univ., Nijmegen, The Netherlands) explored stereopsis under systematically varied figural and random stereogram stimulus conditions. For instance, they made the visible figure noisy to reduce its figurality. The subjects manipulated the luminance until a depth perception was just observable. In general, when the two colors were equally luminous, there was no depth experience.

A special historical exhibit was arranged in the Wren Library of Trinity College. Among the items on display were two Newton prisms, a notebook of Newton's that recorded the 1667 purchase of three prisms, Newton's personally corrected copy of the *Opticks*, Maxwell's color mixing apparatus, and Rayleigh's anomaloscope.

*N.A. Bond, Jr.*

ONR London

## BIOLOGICAL SCIENCES

### ADVANCES IN NUCLEAR MAGNETIC RESONANCE (NMR) OF BIOLOGICAL SYSTEMS

An International Summer School on "Advances in NMR of Biological Systems" was held at the University of Calabria in Rende, Italy, from 28 June to 6 July 1982. The conference was organized by Prof. Filippo Conti of the University of Rome and Prof. G. Chidichimo of the University of Calabria, with the sponsorship of the International Society of Magnetic Resonance. Some 70 scientists from Italy, the US, England, France, Belgium, Sweden, Switzerland, Germany, Canada, and Greece attended the discussions on the utilization of nuclear magnetic resonance (NMR) spectroscopy and some of its biological applications. The purpose of the school was to demonstrate how atomic nuclei such as  $^1\text{H}$ ,  $^2\text{D}$ ,  $^{17}\text{O}$ ,  $^{13}\text{C}$ ,  $^{23}\text{Na}$ ,  $^{39}\text{K}$ ,  $^{35}\text{Cl}$ ,  $^{43}\text{Ca}$ ,  $^{25}\text{Mg}$ ,  $^{31}\text{P}$ , and  $^{15}\text{N}$  are being used today in biological applications.

Proton and  $^{13}\text{C}$  high resolution NMR are used mainly for the structural analysis of pharmaceuticals and biological macromolecules. Cell membrane structure and dynamics can be followed with  $^1\text{H}$  and  $^2\text{D}$  labeled lipids. Proton, deuteron, and  $^{17}\text{O}$  NMR are also used to follow

the behavior of the abundant water of biological systems. Advances in instrumentation, signal averaging and computerization, fast Fourier transform technology, and superconducting magnets have made NMR a practical and useful research and diagnostic tool in the biological and biomedical sciences.

The general theory of NMR, the utilization of fast Fourier transform, and the Overhauser effect were discussed on the first day of the conference as a background for all participants.

Structural and conformational analysis by  $^1\text{H}$  and  $^{13}\text{C}$  NMR of polypeptides and proteins on 360 to 500-MHz spectrometers was the subject of 2 days of discussion. George Gray, (Varian Associates, Palo Alto, CA), described experiments showing that advances in probe technology and higher magnetic fields have also made  $^{15}\text{N}$  NMR of proteins feasible. Assignments of chemical shifts in the NMR spectra of polypeptides can be made from a combination of  $^1\text{H}$ ,  $^{13}\text{C}$ , and  $^{15}\text{N}$  spectra by a technique called multinuclear two-dimensional NMR. Even isomer interconversion can be measured. W. Gibbons (Univ. of Wisconsin), discussed how the conformational structure of organic ring compounds may be deduced from the contributions of the Overhauser effect. H. Ruterjans (Frankfurt, FRG), demonstrated how  $^{15}\text{N}$  spectra can be used to study interactions between a protein (lac repressor) and the nucleic acid gene it controls. Kurt Wuthrich, (Zurich, Switzerland), showed the advantages of 500-MHz proton high-resolution spectra for the analysis of protein conformation.

Probably the most novel application of NMR demonstrated at the meeting was the measurement of ion binding in biological systems. Previous attempts at sodium and potassium NMR had been criticized, but S. Forsen (Lund, Sweden) improved the sensitivity of such techniques by using more concentrated solutions of ions of stable isotopes such as calcium and magnesium and specific proteins to which they are known to bind, such as calmodulin, parvalbumin, and troponin C.

Spectra from  $^{113}\text{Cd}$  metalloproteins have also been observed. Such spectra from quadrupolar ions can provide an estimate of free and bound ions and the exchange rate between the two populations.

Phosphorus-31 NMR is becoming an extremely useful tool in the analysis of biochemical pathways and the bioenergetics of functioning tissues. R. Shulman (Yale Univ.), O. Jardetzky (Stanford Univ.), and P. Cozzone (Marseille, France) described experiments in which intracellular pH and energy production and utilization could be followed in real time in cells, tissues, and yeast spores through the phosphonucleotide spectra of ATP and its products.

Carbon-13 NMR provides additional information about biochemical pathways and preferential degradation paths in organisms as labeled compounds are observed over periods of

time. Both techniques have been used to diagnose diseases and inborn errors of metabolism in human patients.

The final days of the conference were devoted to the use of relaxation times of water protons in living cells and tissues. Since 1972, when R. Damadian first published that NMR relaxation times for water protons in cancer cells tended in general to be longer than for water in normal cells, the diagnostic potential of NMR has been extensively explored by many investigators. However, there remains a great deal of mystery about the origin of the differences in relaxation times between different types of tissues or cells and between cancerous and normal cells. P.T. Beall (Baylor Coll. of Medicine, Houston, TX) and M.M. Pintar (Waterloo, Canada) addressed the role of water-macromolecular interactions in the production of various relaxation times in tissues. The conclusions were that while hydration (or the weight of water per weight of dry solids) is an important component, the type of macromolecule involved, its shape, surface area, surface charge, and conformational state also play important roles in influencing water behavior near the surface. Chromatin, actin filaments and microtubules of the cytoskeleton, and membranes all affect the behavior of water in cells in different ways.

The utilization of NMR relaxation time differences in the diagnosis of cancer has led to the latest addition to biological NMR whole body NMR imaging. Diagnostic machines that combine large magnets capable of holding the human body, sophisticated instrumentation capable of focusing a small volume at resonance frequencies, and the computer imaging techniques of this decade are being used in research centers and hospitals around the world. There was a great display of interest in this part of the program by NMR scientists who hope to introduce the technique to their own countries. David Hoult (National Institute of Health, Bethesda, MD) discussed the theory of imaging, its uses, and its limitations. P. Lauterbur (State Univ. of New York, Stony Brook, ), E.R. Andrew (Nottingham, England), and P. Martin (Oxford Instruments, England) showed how images are made and demonstrated that the imaging technique is capable of displaying human tumors using very low power nonionizing radiation and noninvasive techniques.

The consensus of the participants was that nuclear magnetic resonance spectroscopy has many exciting and beneficial uses in the advancement of our understanding of the structure and function of biological systems.

*P.T. Beall*

Baylor College of Medicine, Houston, Texas

#### A WORKSHOP ON INVERTEBRATE RESPIRATORY PROTEINS

A workshop on the structure and function of invertebrate respiratory proteins was held at the University of Leeds, England, from 18 to 22 July 1982. The conference was sponsored by the European Molecular Biology Organization (EMBO) and was the seventh in a series of such meetings. It was organized by E.J. Wood (Dept. of Biochemistry, Leeds Univ.), aided by a committee that included J. Bonaventura (Duke Univ., NC).

Approximately 100 scientists attended. Most of them came from western Europe, but there was also strong representation from the US and Japan and some from Israel, New Zealand, and Brazil. Contributions to the workshop included about a dozen review lectures given by experienced workers, some 40 oral research communications, and nearly 30 poster presentations of results.

Invertebrate respiratory proteins include a diverse set of oxygen carriers found in the bloods of invertebrate animals. The proteins fall into three basically different kinds on the basis of oxygen-binding center characteristics. Hemoglobins bind oxygen at the iron atom of a heme group, hemocyanins have two copper atoms in the active center, and hemerytherins have two iron atoms. The protein molecules have still greater diversity in structural and functional properties.

The meeting was opened with a review by E.F.J. van Bruggen (Univ. of Groningen) of structural properties of the hemocyanins from arthropods and molluscs as seen by electron microscopy. All hemocyanins are large, multi-subunit proteins with molecular masses as large as several million daltons. However, hemocyanins from the two phyla differ greatly. Those from arthropods are multimers of hexameric structures based on subunits of 70,000 to 90,000 daltons. Progress on the analysis of crystal structures of such hexamers was reported by W.P.J. Gaykema (Univ. of Groningen) and by W. Love and K. Magnus (John Hopkins Univ., Maryland) and the detailed analysis of micrographs of higher aggregates was reported by M. van Heel (Univ. of Groningen).

The considerable subunit heterogeneity in these arthropod hemocyanins was described by B. Linzen (Univ. of Munich). Immunological studies reported by J. Lamy (Francois Rabelais Univ., Tours) and J. Markl (Univ. of Munich) showed that these similar but distinctive subunits have specialized roles. Progress has also been made in the amino-acid sequence analyses of such molecules as reported by A. Riggs (Univ. of Texas), H. Schneider and W. Schartau (Univ. of Munich), T. Nemoto (Tohoku Univ.), and J. Vereijken (Univ. of Groningen). These are among the largest protein chains to be

sequenced, and preliminary efforts are underway to continue the work by DNA sequencing techniques.

R. Lontie (Cath. Univ. of Leuven) discussed molluscan hemocyanins, which are built on a different plan. The molecules are as large as 9 million daltons and have as many as 20 polypeptide chains, each of an unprecedented length. Each chain of some 4,000 amino acids comprises 8 functional units. C. Gielens (Cath. Univ. of Leuven) and others reported on the cleavage of the chains by limited proteolysis into the constituent domains. G. Preaux (Cath. Univ. of Leuven) showed that the units are immunologically cross reactive, and J. Lamy (Francois Rabelais Univ., Tours) showed cross reactions between molluscan and arthropodan hemocyanins.

Annelid worms, some gastropods, certain crustaceans, and even some larval insects use hemoglobin rather than hemocyanin as an oxygen carrier. In some of these the hemoglobins are monomers or small oligomers contained in erythrocytes, but more often they are giant molecules free in the hemolymph. These extracellular hemoglobins are sometimes also called erythrocruorins. Assembly and disassembly results on various annelid hemoglobins were reported by S. Vinogradov (Wayne State Univ., Detroit), A. Chiretti-Magaldi (Univ. of Padova), E. Chiancone (Univ. of Rome), and K. Fushitani (Osaka Univ.). W. Henderickson (Naval Research Lab., Washington, DC) reviewed the symmetrical properties of these and other such macromolecular assemblies and presented a new comprehensive model for annelid hemoglobins. R. Terwilliger (Univ. of Oregon), E. Daniel (Tel Aviv Univ.), and L. Moens (Univ. of Antwerp) described the structures of the polymeric, multidomain hemoglobins that occur in some clams, snails, and crustaceans. A.J. Arp (Univ. of California, Santa Barbara) reported on sulphide transport in the blood of large tube worms found at hydrothermal vents deep off the Galapagos Islands.

Throughout the conference attention was also paid to the functional aspects of the above mentioned oxygen-carrying proteins. H. Kuiper (Univ. of Rome) specifically reviewed the nature of cooperativity in hemocyanins. A. Dawson (Univ. of Leeds), A. Savel (Univ. of Munich), and B. Richey (Univ. of Colorado) among others reported on specific experiments related to the oxygen-binding properties of hemocyanins. Most of the invertebrate oxygen carriers are allosteric proteins and some exhibit extraordinarily pronounced cooperativeness in oxygen binding.

The functional properties of the above molecules are certainly related to the chemistry of their active centers. Pertinent to such chemistry, E. Solomon (Stanford Univ.) gave an extensive review of spectroscopic evidence about the dimeric copper center in hemocyanins. Experiments on the reconstitution of hemocyanin with cobalt replacing the copper were reported

by R. Witters (Cath. Univ. of Leuven) and B. Salvato (Univ. of Padova). Regarding a different active center, S. Sheriff (Naval Research Lab.) presented a detailed description of the active center in hemerythrins.

Hemocyanins have several ancillary activities besides that of reversible oxygen binding. Catalase activity has been demonstrated in arthropod hemocyanins and the active center is known to be related to that in tyrosinases. The tyrosinase activity of hemocyanins was discussed by G. Jori (Univ. of Padova), A. Nakahara (Osaka Univ.) and M. Beltramini (Univ. of Zurich). Some dissociated molluscan hemocyanins can form annular structures that interact with lipid bilayers to form ion channels, as discussed by F. Ghiretti (Univ. of Padova).

The final day of the meeting was primarily devoted to the biosynthesis and genetics of the invertebrate respiratory proteins. E. Wood (Univ. of Leeds) gave a review of the synthesis of such molecules. The messenger RNAs for the multiunit polypeptide chains of gastropod hemocyanins and hemoglobins have been prepared and *in vitro* expression has been demonstrated. The separate chains of *Limulus* hemo cyanin have also been expressed *in vitro*. Clearly the way has been paved for detailed molecular biological study of the genes of these complex systems.

The conference was closed with an evaluation of some unresolved problems concerning hemocyanins by K.E. Van Holde (Oregon State Univ.). Although progress has been truly remarkable in recent years there still are many unanswered questions, especially regarding the heterogeneity, synthesis, assembly, and evolution of such molecules.

W.A. Hendrickson

Naval Research Laboratory, Washington, DC

## CHEMISTRY

### POLYMER RESEARCH AT THE PROPELLANTS, EXPLOSIVES AND ROCKET MOTOR ESTABLISHMENT (PERME), WALTHAM ABBEY, ESSEX, UK

Basic polymer chemistry research at PERME is being carried out in synthetic polymers and in nitrocellulose. The work of the two groups is described in the following paragraphs.

#### SYNTHETIC CHEMISTRY GROUP

The research and development is under the direction of Dr. D.H. Richards, a distinguished scientist who was recently awarded the Courtauld Medal by the Royal Society of Chemistry. The main activity is the synthesis of novel, mainly energetic compounds for use as



ingredients for explosive and propellant compositions.

The group is currently developing new energetic binders for rubbery propellants. The systems normally consist of an oxidant (ammonium perchlorate) and an elastomeric binder, hydroxy terminated polybutadiene (HTPB), that is cross linked with isocyanates. Because the polymer also acts as the fuel, it is ideally required to hold 9.6 times its own weight of oxidant in order to get total conversion to  $H_2O$  and  $CO_2$  on combustion. Clearly such loadings are difficult to achieve, and this gives impetus to the search for elastomeric binders containing energetic ligands, such as nitrate and nitro groups, in order to be able to reduce the extreme loading requirement.

An excellent account of conventional propellant systems and of current US approaches to preparing energetic binders may be found in the review by R.S. Miller, P.A. Miller, T.N. Hall, and R. Reed published in *Naval Research Reviews*, 33, (2), 21-36 (1981). In the UK, Richards' group has "energized" HTPB by introducing nitrate ligands onto the polymer at the points of unsaturation, i.e., the conversion of  $-CH_2-CH=CH-CH_2-$  units to  $-CH_2-CH(ONO_2)-CH(ONO_2)-CH_2-$  has been effected. When 20% of the double bonds have been converted, the material still retains its elastomeric properties on cure with conventional isocyanates, and calculations show that the ammonium perchlorate-polymer weight ratio can be reduced to 5.9.

Techniques have been developed to synthesize difunctional, high 1,4 content polybutadienes anionically in tetrahydrofuran (THF). Normally, the polybutadiene resulting from polymerization in this "good" solvent possesses 90% vinyl structure and consequently is a poor elastomer when cured. However, it has been shown that the addition of a sterically hindered Lewis acid, such as trimesityl boron, to such systems modifies the propagating anionic end to increase the 1,4 content. The degree of increase is a direct function of the relative amount of Lewis acid present, and so far 1,4 contents in excess of 50% have been obtained.

Other anionic processes have been devised that allow the synthesis of polydienes with terminal ionic groups such as quaternary ammonium salts and tetraalkyl borons. Such groups, in the presence of the nonpolar matrix, cluster into ionic micelles and the materials consequently exhibit thermoplastic elastomeric properties. A number of examples of the new class of polymers have been prepared and their properties are being evaluated. It is anticipated that they will exhibit strong adhesion to any polar or unsaturated filler that is introduced.

The group is involved in developing an electrolytic method of preparing  $N_2O_5-HNO_3$  solutions, a process originally worked on at the Lawrence Livermore Laboratories. The solutions

are powerful nitrating agents and are to be used in a new method of preparing cyclotetramethylenetetranitramine (HMX) free from cyclotrimethylenetrinitramine (RDX). The current method of synthesizing HMX (Bachmann process) yields mixtures of the two explosives although their relative proportions are controllable. Separation into two pure compounds is difficult because of structural similarity; the group has recently developed, however, a method of extracting HMX from such mixtures with a purity of >98% by complexation with dimethyl formamide (DMF).

As the PERME group is the only synthetic chemistry group in the MoD, it provides general synthesis expertise to other establishments within the ministry, and so a significant fraction of its time is devoted to the preparation of polymeric and high-energy materials for formulating and testing elsewhere. For example, some effort is being devoted to the synthesis of amino derivatives of tetryl in the search for powerful explosives with enhanced thermal stability.

The group maintains a close liaison with the chemical engineers at PERME and provides the thermodynamic and kinetic data on reactions to be scaled up to pilot-plant and ultimately to production levels. Examples of such developments include the synthesis of hexanitrostilbene, sym-triaminotrinitrobenzene and various styrene-butadiene latices.

#### NITROCELLULOSE GROUP

The group is under the direction of Dr. T.J. Lewis, who is well known for his accomplishments in the field. Extensive work on the characterization of nitrocellulose (NC) has included x-ray studies, birefringence molecular conformations, and molecular weight distributions. The effect of the latter on processability has been investigated in detail and is found to be significant. A wide distribution has been found to be better because the smaller molecules act as adhesives between the fibers for certain kinds of casting powders. An excellent paper on some of these effects has recently been published [T.J. Lewis et al., *J. Hazardous Materials* 5 269-276 (1982)]. Bimodal distributions have also been found and have been ascribed to the different accessibilities of the original cotton linters.

Extensive studies of the propellant structures have been conducted and are still in progress. Relaxation techniques include dielectric spectroscopy, dynamic mechanical analysis, pulsed NMR, and DSC studies. Interesting effects are found with the  $\alpha$  and  $\beta$  relaxation peaks as a function of the nitroglycerine content. Decomposition and burning behavior have been investigated in depth. Finally the diffusion of nitroglycerine simulants into nitrocellulose has been under investigation. Case III diffusion was found with isopropyl nitrate and acetone; this differs from the well-known Case II mechanism. In particular the rate of uptake of the penetrant is independent of the film

thickness. This implies that the film is expanding uniformly with no appreciable concentration gradients and with rapid Fickian diffusion compared with the relaxation processes. With Case II, Fickian diffusion through the unexpanded lattice is effectively zero. A fuller discussion of this so-called Case III mechanism together with experimental results may be found in *Polymer*, Vol. 23, pages 144-146 (1982). The amount of sorption is controlled by the extent of lattice relaxation. Such studies provide a method of measuring the extent of relaxation and are of considerable fundamental interest.

*V.T. Stannett*

ONR LONDON

## COMPUTER SCIENCES

### THE UK END OF THE DARPA INTERNET

In a recent interview with Mr. Robert H. Cole, University College, London (UCL), the author discussed the implementation of the interconnection of the US Defense Advanced Research Projects Agency (DARPA) Internet with several networks in the UK. The facility is designed to support interactive terminal traffic, file transfer, electronic mail, and research into network interconnection.

The ARPANET, a packet-switched network, was developed by DARPA in the late 1960s. It has since grown into a nationwide network connecting more than 150 computers of many different manufacturers.

The DARPA Internet is centered on ARPANET, on which most of the service hosts reside. The process of internetting is the interconnecting of two or more networks. Such an interconnection is effected by a small computer, called a gateway, which performs the addressing and format conversion functions needed to pass information from one net to the other. A number of nets are attached to the periphery of the ARPANET by gateways. One of the nets is SATNET (Satellite Network), which accesses the ARPANET through a gateway in Boston, referred to as the BBN gateway after its implementers, Bolt, Beranek, and Newman. SATNET is called a transit network, as it has no hosts other than gateways. (See Fig. 1 for details.)

Besides the ARPANET Connection SATNET is connected via gateways to UCL, the Norwegian Defense Research Establishment, and Deutsche Forschungs und VersuchsAnstalt für Luft und Raum-Fahrt (DFVLR) in Raisting, West Germany. Each of the networks supports the DARPA transmission protocol as they are a part of the DARPA Internet. Thus, the DARPA Internet consists of a number of networks interconnected by gateway hosts. Each network

in the system has its own internal data transmission protocol used to convey internet datagrams. The gateways only process datagrams and they contain no call state information.

The DARPA Internet datagrams are routed individually by the originators and the intermediate gateways. Each packet carries a specification of the destination network. For networks other than the local network a routing table is consulted to choose the appropriate gateway. The routing table is built dynamically, based on routing information in packets exchanged by the gateways.

The ground station for SATNET in the UK is at Goonhilly. The full bandwidth transmission rate on SATNET is 64 kbps. Goonhilly has a permanently enabled direct route to the US ground station on SATNET at Etam, Virginia. However, this is at half bandwidth capacity, 32 kbps. Through the gateway at University College, connected to the Goonhilly ground station, a number of other nets in the UK have access to SATNET.

British TELECOM, like a number of other national postal, telephone, and telegraph (PTT) agencies, has adopted the Comité Consultatif International Téléphonique et Télégraphique (CCITT)- recommended X.25 protocol as the standard service interface over its Packet Switched Service (PSS). Also, SERCNET, a private network of the UK academic research community operated by the Science and Engineering Research Council (SERC), has been moving rapidly toward compatibility with British TELECOM's PSS, including Protocol X.25 and the user defined protocol above it.

PSS is connected to the US Value Added Networks (VANs) through British TELECOM's International Packet Switching Service (IPSS). Such internetting of public data networks is planned by many countries and their PTTs are building gateways to effect it.

University College London has inter-connected the DARPA Internet and the PTT X.25 Net by successfully dealing with the differences in protocol, addressing, and routing mechanisms. The UCL Gateway can route traffic through the SATNET Access Machine (SAM) to and from the Cambridge Ring, a 10 mbps raw data ring. Another computer on the Cambridge Ring labeled X.25 (Fig. 1) is connected to SERCNET and to PSS.

Thus UCL is a host on the X.25 network to SERCNET and TELECOM's PSS. PSS uses X.121 addressing (of the International Telephone System), which allows UCL a 2-digit subaddress field for service selection. SERCNET relies on symbolic subaddressing in the Network Independent Transport Service (NITS), defined by a UK users' group, which enhances the facilities of the PTT X.25 Network PSS. The interconnection facility operates as a host for the DARPA Internet, and the Transmission Control Protocol (TCP) port number is used for service selection.

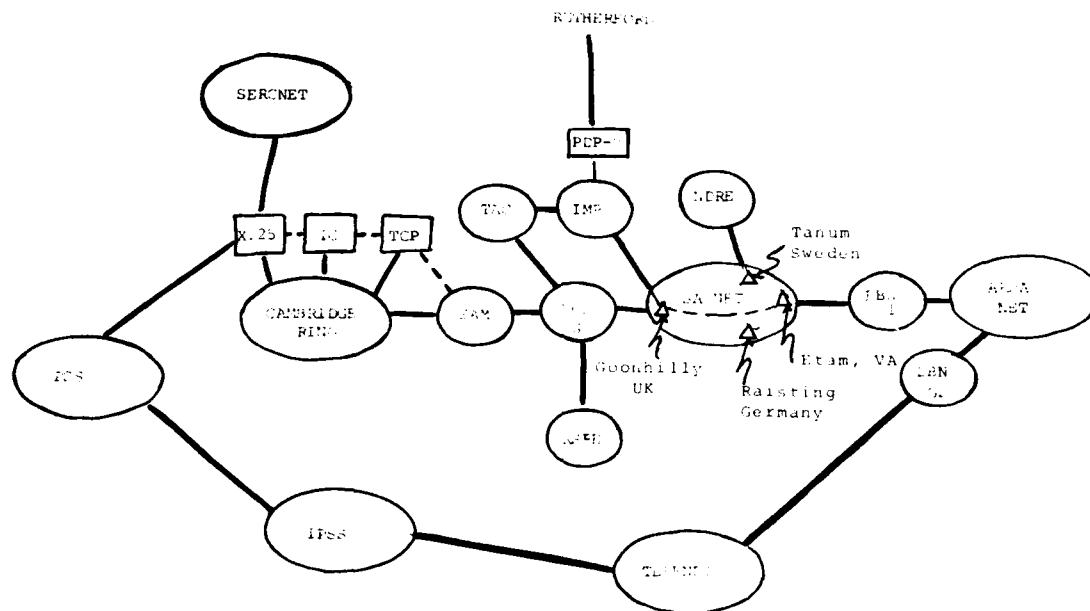
There are two paths from UCL to the ARPANET. The route via SATNET for work

sponsored by the Ministry of Defense (MoD) or by DARPA uses the Atlantic Packet Satellite Network as a transit network. The operating costs of the SATNET connection in the UK are paid by the Ministry of Defense. The MoD and British TELECOM will permit SATNET use only for work sponsored by the MoD or by DARPA.

Nonmilitary sponsored users, e.g., aca-

passed through a private circuit directly to the Goonhilly ground station and thence to ARPANET via SATNET. Other messages can be routed from IMP to the Terminal Access Controller (TAC) to the UCL gate.

Besides TELECOM's PSS and SERCNET, previously mentioned, there are a number of other connections to the Cambridge Ring for a



PSS: British Telecom Packet Switching Service  
IPSS: International Packet Switching Service  
X.25: Network Access Machine  
TG: Terminal Gateway  
TCP: Transmission Control Protocol  
SAM: SATNET Access Machine

TAC: Terminal Access Controller  
 SERE: Royal Signal And Radar Establishment  
 NDRE: Norwegian Defense Research Establishment  
 BBNG1: Bolt, Beranek And Newman Gateway  
 BBNG2: Van Gateway  
 IMP: Interface Message Processor

Figure 1

demarc users, use a second path via a PTT provided service, the three network system. PSS-IPSS-Telenet, to cross the Atlantic. To achieve this Internet Protocol (IP) datagrams are encapsulated within X.25 packets at UCL. Such datagrams pass through an Internet gateway in Boston called the VAN Gateway. A call is initiated at UCL on PSS by giving the X.121 address of the VAN Gateway. The gateway functions as if communicating with a network and performs as a normal DARPA Internet gateway. The device is used merely for transporting datagrams across the Atlantic legally.

The Royal Signal and Radar Establishment at Malvern has access to SATNET through the UCL gateway. Also the Rutherford Appleton Laboratory has access to SATNET through a line controlled by a PDP-9 (at UCL) through the Interface Message Processor (IMP) where messages sponsored by MoD and DARPA can be

variety of purposes including research and service. All the networks terminate at computers attached to the Cambridge Ring. The computers are called network access machines, and they contain the protocols for that network and processes to direct data to and from other ring hosts, using an interprocess control. There are two UNIX systems (run on PDP-11's) connected to the ring. The systems support the protocol NIFTP (UK-developed Network Independent File Transfer Protocol) that can be used to reach PSS, SERCNET, Internet hosts and the Internet Terminal Protocol TELNET. NIFTP is used for both file and electronic mail transfers between the UK and the US.

It has already been mentioned that the Rutherford-Appleton line is controlled by a PDP-9. The terminal access controller (TAC) function is handled by a Honeywell 316, as is the Interface Message Processor (IMP). The terminal gateway is controlled by 3 LSI-11's and

the UCL gate by a PDP-11/35. All of the systems are housed at University College.

*J.F. Blackburn*

ONR London

## ELECTRONICS

### MONOLITHIC MICROWAVE FLOURISHES AT CISE

The Center for Information, Studies, and Experiences (CISE) in Milan, Italy, was founded in 1948 as a private research company primarily for the study of nuclear physics. Today it has broadened its fields of study to include civil engineering, quantum electronics (lasers), solar cells, materials (both electronic and mechanical), microwave devices and circuits, instrumentation, and bioelectronics. CISE employs 500 people of whom 35% are professionals.

The electronics group, with 50 people, has three sections: devices, microwaves, and instrumentation. The gallium arsenide (GaAs) field effect transistors (FETs) group is the largest. G.P. Donzelli routinely fabricates X-band FETs characterized by T-shaped control gates whose dimensions are  $0.5 \times 200$  micrometers and larger. Both arsenic trichloride-based vapor-phase epitaxy (VPE) and ion-implantation processes are used. A new 400 KEV Accelerators Incorporated ion-implantation machine is used for both silicon and selenium implants. Annealing, which takes place at  $800^{\circ}\text{C}$ , is capless in an arsine atmosphere. Silicon implants are annealed in 10 min and selenium implants in 30. Electron beam evaporation of aluminum gates is used in conjunction with standard gold-germanium-nickel contacts, and ion milling has extensive application in fabricating on-chip matching circuitry. A Karl Zeiss mask aligner is also used. The special feature of the aligner is that it "contact prints" while holding the mask  $1 \mu\text{m}$  above the substrate and thus avoids mask deterioration. With a deep ultraviolet light source it is capable of  $0.85 \mu\text{m}$  resolution. Smaller gate structures are made by etchback techniques.

The experience gained in using FETs has enabled N. Fanelli to develop single-stage and three-stage monolithic microwave integrated circuits (MMIC) in both microstrip and coplanar waveguide technology. The goal in MMIC technology is to develop a satellite-to-home TV broadcast receiver front end by September 1983. In addition to the three-stage preamplifier, a dual gate mixer and a direct-coupled intermediate frequency amplifier are being developed for a private customer. Although CISE is not under contract to develop the local oscillator for this receiver, the group has independently developed a barium titanate cavity resonated oscillator. A universal problem with MMICs has

been the yield of metal insulator metal (MIM) parallel plate capacitors. While others have used air-bridge connections to avoid short circuits at capacitor edges, CISE has gone a step further and has used magnetron sputtered silicon dioxide dielectric that is subsequently annealed in the ohmic contact sinter operation. This produces an ultrasmooth dielectric.

Considering their late start in the GaAs MMIC field, the workers involved in the above effort have made outstanding progress. They have conceived a way around the turnaround time from mask design to fabricated product testing, which generally takes 6 to 16 weeks. Their method also largely overcomes the problem of yield brought about by fabricating submicrometer devices on an MMIC also incorporating devices whose gate lengths exceed  $1 \mu\text{m}$ . Although the approach is proprietary, they plan to announce it at a regional European MMIC meeting to be held in London in December. Using the new method there is a high probability that they will meet their goal of a 30-db gain, 5-db noise figure, 11.7 to 12.5-GHz receiver by September 1983. Overseeing the effort is a former nuclear physicist, Dr. Ezio M. Bastida, who initiated the CISE activity in solid-state devices in 1968.

Instrumentation is also a major field of endeavor at CISE. Using a low-power GaAs Gunn diode oscillator, investigators have developed an apparatus for characterizing soil samples by their dielectric constant and loss tangent. One interesting adaptation of this instrument is to measure the thickness of concrete after it has set. The instrument can also measure concrete strength by correlating dielectric constant and loss tangent with moisture content. Another variation of the instrument greatly simplifies the pouring of steel castings. Whereas gamma rays were previously used to detect the liquid steel level in a casting as it cooled, a much safer 1 milliwatt microwave system is now used.

Italy was the pioneer in tapping sources of geothermal energy and still has the largest number of active wells. To exploit geothermal energy better, a simple yet reliable means is necessary to determine temperatures along the depth of the well. S. Mezzetti has developed a lithium niobate cell that changes its index of refraction and polarization properties as a function of temperature. The cell is attached to the end of a 4-km-long stainless-steel-clad fiber optic cable through which polarized light is transmitted. A LED light source is used and its output is scanned by a Fabret Perot device to scan at  $40\text{-}\text{\AA}$  parts of the spectrum. Temperature resolution is said to be  $0.01^{\circ}\text{C}$ .

M. Bassini has developed several bioelectronic instruments. The first of these is a 240-point contact electrocardiograph instrument that displays a two-dimensional profile of the cardiac generated potentials across the entire chest (or back) area. It can display the potential profile as a function of the cardiac

cycle. Bassini has also developed an ultrasonic device to measure the velocity profile of blood flow through an artery. Working with Dr. Pignoli of the Polyclinical Hospital of Milan, he has been able to detect narrowing of the arteries of the neck by plaque buildup. It is thought that the technique may be useful in detecting incipient strokes. The attractiveness of the method lies in its nonintrusive nature.

CISE has a long history of cooperation with the electric power industry. C. Flores is currently working on the development of bispectral solar cells. He uses both liquid phase epitaxy (LPE) and organometallic (OM) VPE to fabricate the devices. A three-terminal GaAs-GaAlAs device is currently under development. It uses 1.4- and 1.7-volt diodes connected in series and has produced 16% efficiency, which Flores believes he can almost double. For the cells to be economically efficient, however, a process must be developed to salvage the single crystal substrates on which the active devices are grown, a problem that is currently occupying most of the effort.

As a private organization with no production capability or parent financier, CISE is constantly searching for support. It depends strongly on government support and operates entirely on contracts, some of which are US sponsored. With a long list of achievements and knowledgeable staff, it is an organization that can be expected to continue to be recognized.

M.N. Yoder  
ONR London

## MATERIAL SCIENCES

### FULMER RESEARCH INSTITUTE, LTD

The Fulmer Research Institute (FRI), Stoke Poges, Slough SL2 4QD, England, includes the Fulmer Research Laboratories (FRL) and Fulmer Technical Services (FTS), both at the home address, and three other units: Fulmer Components (FC) Ltd, at 232 Berwick Avenue, Slough SL1 4QD; Yarsley Research Laboratories (YRL) Ltd, The Street, Ashted, Surrey KT21 22AB; and Yarsley Technical Centre (YTC) Ltd, Trowers Way, Redhill, Surrey RH1 2JN. Since its founding in 1946 to do research on aluminum for projected aerospace requirements, the FRI has grown to a total income for its business activity in 1981 of more than \$5M. In 1965 the FRI came under the ownership of the Institute of Physics. E.I. Salkovitz wrote a description of The Fulmer Research Institute as ONRL Report R-63-70, just after the 1969 appointment of Dr. W.E. Duckworth to the managing directorship. Duckworth was host for our 1982 visit to the

FRI. The chairman of the Fulmer Research Institute is Sir Ieuan Maddock, FRS.

The FRL and YRL do research and development on a broad range of materials, products, and processes. The FTS and YTC are involved with NATLAS, the National Testing Laboratory Accreditation Scheme formed by the UK government to establish standards and quality criteria for manufactured products. Fulmer carries out testing programs related to professional competence, facilities, and management structure. The unit is a manufacturer of electronic components and instruments. The FRI Wear Debris Monitor is an example of a recent innovative FC-type product developed within FRL (see the description by D.R. Barr, "Detection of Wear Debris in Lubrication Fluids," *ESN* 36-8:197 [1982]).

Our visit to FRI began with presentations by a number of members of the FRL staff moderated by Eric Duckworth. David G.S. Davies spoke about three efforts relating to research planning for managerial persons (see D.R. Barr, "A Research and Development Decision Aid," *ESN* 36-8:182 [1982]), programs to promote technology transfer (within overseas countries), and teacher education connected with employment opportunities for graduating students. Dr. Martin A. Moore described the commercial Fulmer Materials Optimizer information system that contains the cumulative knowledge the staff has gained on the performance, cost, and manufacturing aspects of product developments for metal, plastic, and ceramic systems (see I.M. Bernstein, "Materials Selection Made Easier," *ESN* 32-7:241 [1978]). Martin Moore described the nature of Fulmer's contract work on materials-related product development by citing two examples: first, the total design package of an infrared tracking unit; and, second, the Black and Decker work bench for which curing of the adhesive used in the product became the controlling factor in determining the speed at which the benches could be fabricated. Greville B. Brook, who is also Visiting Reader at the Department of Metallurgy and Materials Technology, University of Surrey, spoke about efforts to produce new and improved materials and research activities concerned with developing improved metal alloy casting procedures. Brook cited the production of aluminum alloys with improved strength and corrosion properties by the control of trace elements, which achieve their purpose through atomic vacancy interactions. Copper-based shape-memory alloys have been developed. A proprietary casting procedure was developed that was claimed to be very competitive with rheocasting, and research is done on continuous casting. In the physics area, Duncan Stewart spoke about the directional solidification of refractory carbide or boride fibers in suitable eutectic systems to produce electron field emitters. Work has been going on to produce materials by chemical vapor deposition, most recently boron nitride. The wear debris

monitoring of lubricating oil quality involves the measurement of the changed resistivity of a nichrome sheet material arising from erosion by particles picked up within a circulating oil system. Dr. William H. Bowyer spoke about two defense-related areas of research for military applications at FRI, the development of lightweight protecting armor and the development of glass-fiber reinforced plastic (GRP)-hulled mine sweepers. The work on GRP for the UK Ministry of Defence now involves composite materials reinforced with a number of different fibers.

Our impression during the initial presentations was that a major strength of FRI is the stability of the organization, the number of long-running projects, and the employment tenure of competent persons. The presentations emphasized the idea that expert knowledge had been gained in a number of materials subjects that the staff turned into useful practical products in an industrial or defense-related environment. FRI is frequently in communication with Battelle but otherwise sees itself as a competitor for contracts against Battelle and other US-based organizations, such as the Stanford Research Institute, the A.D. Little Corporation, and other university-based research laboratories. The five FRI units, FRL, YRL, FTS, YTC, and FC produce information sheets on research subjects, products, processes, testing, information services, etc., for establishing contacts and answering inquiries.

## METALS

### Trace element strengthening in Al alloys

The activity is an outgrowth of an original research effort "to investigate precipitation phenomena in high-purity alloys, with special reference to the effects of third elements on precipitation phenomena in high-purity aluminum 4% copper alloys" (G.B. Brook, Precipitation in Metals, Special Report No. 3, A Review of Work at Fulmer Research Institute 1947-1963, prepared for the UK Ministry of Aviation Party on Precipitation). Forty references, slightly more than half of which are published, are quoted in Brook's report describing x-ray, hardness, and specific heat measurements on a variety of Al-Cu alloys including Cd, In, Sn, Li, Ag, or Ga additions. Copies of the report may be obtained directly from Greville Brook.

A modern reference to the continuation of this work with combined magnesium and germanium additions is by Brook, "The influence of trace elements on the control of properties of high-strength creep resistant alloys" (Aluminum Alloys in the Aircraft Industry, Symposium held in Turin, Italy, 1-2 October, 1976, Technicopy Ltd, Stonehouse, Gloucestershire, England GL20 2NA, UK p. 185-193). Development work is described for a number of alloys, for example, an Al-5.3%Cu-0.32%Mg-0.12%Si-0.1%Ge-0.5%Mn-0.25%Fe alloy. The work has resulted in an experimental designation of an alloy, Alcan GBX158, for use in the aircraft engineering

industry. To date, approximately 100 tons of the alloy have been produced in plate and sheet form for continued evaluation. An alloy containing 5%Cu and 1%Li was also described.

There is considerable proprietary work on alloy systems because it is felt that the trace elements control nucleation and diffusion processes at precipitation sites in a way related to the properties of the precipitate-matrix interfaces and the development of a dislocation substructure surrounding the precipitates. The trace elements are believed to interact strongly with the vacancies involved with the copper diffusivity during the formation and growth of Guinier-Preston zones. Besides x-ray diffraction, electron microscope and anelastic measurements have been used to describe the processes involved. The strength levels, creep resistance, fracture toughness, thermal stability, and corrosion resistance are normally considered in the design of the alloys.

### Directionally solidified eutectic (DSE) composite field emitters

Fulmer has been involved with the design of field emission cold cathodes. In contrast to the former manufacture of such items as mechanically-pinned composite structures, they can now be designed on the microstructural level as directionally solidified eutectic composites. The noncontinuous metal carbide phase, say vanadium carbide or a refractory metal boride, is produced as a regularly arranged fiber structure in a suitable matrix phase such as Ni and is chemically etched to produce a "wire brush" bed of protruding needle points serving as the electric field-induced electron emitters. The processes by which a proper state of protrusions of sharpened needle points can be obtained by etching and even microfracturing is interesting (see for example, D. Stewart and P. Wilson, "Recent developments in broad area field emission cold cathodes," Vacuum 30, 527-32 [1980]).

Current support for the Fulmer work in the above area is provided by The European Space Agency (ESA) and by The European Office of Aerospace Research and Development (EOARD). Pulsed cathodes with large current densities and reasonable lifetimes can be produced. Needles with a diameter of 1.0  $\mu\text{m}$  and spacing of points of 20  $\mu\text{m}$  can produce a current density of  $10^3 \text{ A/cm}^2$ . Electron (and ion) source thrusters are of interest for space applications but multiple uses are known to exist for devices to inject electrons into vacuum, fluids, or gases. An industrial application of such a device for boiler gases or stack effluents occurs if electrons are injected into the gas mixtures so as to produce charged droplets that can be collected. For whatever electrically related use, such DSE materials have to have good strength properties as well, but in contrast to the sole mechanical property consideration for structural in-situ composites where increasingly packed densities of fibers

are desired for strength purposes, the electrical purpose leads to the need for fibers being appropriately separated. Also, the desired geometry is to have sheet material with the fibers orthogonal to the plane of the sheet.

#### Martensitic transformation shape-memory alloys

The development of shape-memory alloy systems is a second area of research at Fulmer relating directly to the influence of microstructure and the basic deformation systems of a material on its mechanical properties. The work has been connected directly with the Raychem Company in the US and a number of patents are held jointly.

Fulmer has developed a copper alloy for fasteners that is supposed to be superior to that of the established titanium-nickel system. The work has carried over from earlier Fulmer investigations of the crystallography of uranium-molybdenum martensitic alloys showing the shape-memory property. The alteration of damping properties for any of the shape-memory alloys according to their thermally-treated condition, especially to produce a high damping material, is striking. In addition to shape-memory alloys being used for lightweight tube couplings in aerospace applications, such material has recently been used in a satellite boom latch and release mechanism. Sponsorship was provided by the European Space Agency. The British Aircraft Corporation, Electronics and Space Systems Group, has been involved with the manufacture and successful testing of the unit.

#### POLYMERS AND PLASTICS:

Work in these areas is mainly concentrated at YRL and YTC. The two Yarsley laboratories were founded in 1931 by Dr. V.E. Yarsley O.B.E., a well-known polymer and plastics expert. Together YRL and YTC employ nearly 100 people. The YRL conducts or has conducted research on almost every aspect of applied polymer science and technology. A FRI important work is being carried out on fiber reinforced composites.

#### Fiber reinforced composites

The work is under the direction of Dr. William H. Bowyer and involves both rubbery and glassy polymer matrices and carbon, glass, and Kevlar fibers and their combinations. New resins are also being developed and new molding techniques studied. Ballistic impact resistance is being tested and researched with standard procedures and also with newer fragment simulators traveling at velocities up to 500 m/sec and ball and armor piercing rounds of calibers up to 9 mm and velocities up to 1000 m/sec. Fatigue tests from -55 to +120°C, long term, short term, and in water are also being conducted.

Techniques for repairing aluminum aircraft skins, useful for unskilled personnel, with polyester and epoxy composites have been successfully developed. Glasslike composites

are being developed for lightweight protective armor and for mine sweeper hulls.

#### Polymer synthesis and processing (YRL)

Examples of polymer synthesis include flame-resistant polymers, hydrogels for soft contact lens and for inside regular glasses, and high-softening low-loss membranes as capacitor dielectrics. Chelating polymers for wet primers for steel, reactive adhesives, primers for underwater, corrosion resistant polymer and adhesives for wet surfaces in general and other specialty adhesives are also being investigated.

Of special interest is a multi-client project for developing and setting up a production facility for piezoelectric polyvinylidene fluoride film. The project is well advanced and continuous films about 25 cm wide and 30 micron or 8-9 micron thicknesses are being produced. The films, already poled and metallized, will shortly be readily available. The measured piezo coefficients are 27 picocoulombs per newton ( $d_{31}$ ) and the voltage in the same direction 0.166 volts per millinewton ( $g_{31}$ ),  $dt$  (compression) in 19.9 pc/n and  $dh$  8.8 pc/n. The values appear equal to or better than the best Japanese or Pennwalt values. Metallization can be with Al, Ni, Au, etc., on one or both sides.

Other areas of research include the manufacture of various very thin polymer films 2' wide and 1 to 2 microns thick, free of pinholes, and intumescent and other fire-resistant coatings. A separate department manufactures up to 20 Kg lots of specialty chemicals with a special interest in organo-fluorine compounds including monomers.

#### Polymer and plastics technology (YTC)

The YTC has a different mission, specializing in development, testing, and technical advice regarding a wide variety of plastic materials. This includes unique hot runner injection molding design and production using a special polymer transfer system. The equipment and expertise are also available for the short-run production of polymer products.

The testing facilities are varied. The thermal conductivity equipment and expertise is probably the best in the UK and covers long-term testing of all types of materials between -196°C to +1100°C.

Fire testing of all kinds, available on virtually every scale and type, is another speciality of YTC and is approved by a number of agencies. The equipment includes specially designed furnaces for fire resistance testing and for estimating the surface spread of flame and for roof tests. New methods are under development and the accompanying emission of toxic products and smoke density is being studied in detail.

*R.W. Armstrong*

*V.T. Stannett*

ONR London

## METALLURGICAL PROGRAMS AT TWO AERO-SPACE RESEARCH CENTERS

West Germany and France have active aeronautical and space-related research programs. Part of the research in West Germany is carried out in the centers of the Deutsche Forschungs und Versuchsanstalt für Luft und Raumfahrt (DFVLR) while in France part is accomplished by the Office National d'Etudes et de Recherches Aéronautiques (ONERA). Recently, the author visited the materials laboratories of both organizations.

### DFVLR

DFVLR employs about 3,200 people of whom 1,000 are scientists. It operates research centers in Braunschweig, Göttingen, Cologne-Porz, Stuttgart, and Oberpfaffenhofen. Almost 90% of its annual operating budget of about 3 million DM consists of subsidies from the Federal Ministry of Research and Technology (60%), the Federal Ministry of Defense (18%), and local states (7%); the remainder comes from contract research.

The Department of Materials and Structures is one of five research departments in DFVLR. Its headquarters is at the research center in Stuttgart, but four of the department's five constituent research institutes are at other centers. The Institute for Materials Research, under Prof. Dr. W. Bunk, is at the center in Cologne-Porz and is comprised of about 100 people including 35 scientists. Materials research is conducted in five departments: Materials Technology and High Temperature Testing, Microstructural Analysis, Corrosion, Fracture Mechanics and Mechanical Stressing, and Fatigue Testing Under Service Conditions. In addition to its own in-house research programs, the institute is responsible for technical management of a large project funded by the German Ministry for Research and Technology aimed at materials conservation and carried out by both contract and in-house research programs. It has two primary points of focus: (1) the development of materials and methods for substituting ceramic materials for expensive and difficult-to-obtain metallic materials, and (2) the lengthening of product lifetimes by development of improved friction and wear materials. Much research interest centers on the use of silicon nitride and silicon carbide in heat exchangers and turbosuperchargers for automotive applications.

Dr. G. Wirth, who is deputy to Bunk, heads the Materials Technology and High Temperature Testing Department. The research in this department is aimed at improving the properties of currently used aerospace materials by control of microstructure and the development of new materials for aerospace applications. Examples of the first type of research are found in recently completed studies of the

influence of crystallographic texture in  $\alpha + \beta$  Ti alloys, such as Ti-6Al-4V, on fatigue crack growth rates in NaCl solutions, which showed that variations in texture could result in a doubling of crack growth rates. Similarly, studies aimed at improving ductility in aluminum-lithium alloys by microstructural control are in progress, and research on the influence of texture and grain structure on the tensile and fatigue strength of the high-strength aluminum alloy 7475 has recently been completed. In the area of new alloy development, several programs on composite alloys have been accomplished. Among them were an attempt to improve the stiffness of titanium alloys by incorporation of SiC fibers (a 50% improvement in Young's modulus was produced by fiber additions of 14 vol %) and a study of W and W-ZrO<sub>2</sub> fiber-reinforced, nickel-base superalloy composites that showed the influence of nickel diffusion along the fiber grain boundaries on composite property degradation. There is also continuing interest in the use of powder metallurgy processing for alloy production, and programs are being conducted to study the effect of processing on properties of 2024, 2124, 7075, and 7175 aluminum alloys and Ti-6Al-4V and IMI 685 titanium alloys. Powders for these projects are obtained from a large number of outside sources (no powders are produced in house) with processing studies conducted within the department. The objective of the programs is to bring about an improvement in fatigue properties by compositional and microstructural control. Another activity is research on coatings for protection of superalloys from oxidation and hot corrosion. For the most part, the research deals with PVD overlay coatings of (NiCo)CrAlY for application to directionally solidified eutectic and single-crystal alloys, with emphasis on interdiffusion problems, thermal shock resistance, and thermal expansion compatibility.

Research in the Microstructural Analysis Department, headed by Dr. G. Ziegler, concentrates on the development of ceramic materials for high-temperature structural applications, the correlation of ceramic microstructures with mechanical properties, and development of methods for characterizing ceramics and their properties. While some of the work deals with SiC, most is concerned with Si<sub>3</sub>N<sub>4</sub>, and extensive investigations have been carried out on both reaction-bonded and hot-pressed material. Correlation of phase composition, size, and shape of starting powder with density and pore distributions in the resultant bulk material has been carried out, as have correlations with mechanical properties of the bulk product, especially thermal shock resistance. For the past 2 years hot isostatic pressing has been done in a press capable of pressures of 2,000 bars at 1,750°C. The temperature capability is soon to be extended to 2,000°C. Of particular interest in all consolidation processes used for silicon nitride is the role of sintering aids (necessary to achieve reasonable densification)



on the consolidation process itself and the influence of the aids on the mechanical properties of the consolidated material. Other recent research in Ziegler's department has been directed to the development of specimens and four-point bending tests for measuring the fracture resistance of hot-pressed silicon nitride, hot-pressed silicon carbide, and reaction bonded silicon nitride, and to the development of rapid methods for determining fracture resistance based on measurements of Knoop and Vickers hardness impressions.

Dr. H. Buhl is in charge of the Corrosion Department. The research there is primarily concerned with determination of the stress corrosion susceptibility of aircraft materials and the development of testing methods for rapidly determining stress corrosion resistance. For several years the work has been aimed at assessing the usefulness and limitations of Parkins' constant strain rate test and has involved tests with steels, titanium alloys, and aluminum alloys, (2024, 7010, and 7050 alloys) in various heat-treated conditions. While the work has shown the broad applicability of the constant strain rate test for determining stress corrosion susceptibility and its agreement with results gained from constant load tests, it has also identified some of the test's limitations. In particular, the research has been useful in pointing out problems with the test in the case of high strength aluminum alloys.

The Fracture Mechanics Department, headed by Dr. G. Marci, is exploring three avenues: (1) development of failure criteria for thin-walled structures using the R-curve concept and failure-assessment diagrams, (2) development of new test specimens and methods for determining fracture toughness values for materials with moderate toughnesses, and (3) development of techniques for applying linear elastic fracture mechanics methods to composite materials. In the fatigue area, stress-strain conditions at crack tips are being characterized to determine the effective stress intensity ( $\Delta K_{eff}$ ) more accurately, and for this research a new optical filtering technique has been developed for measuring strain. In addition, the threshold stress intensity is being investigated to determine the degree to which it may be considered a material constant.

Dr. H. Nowack is in charge of the Fatigue Under Service Conditions Department. As the title indicates, fatigue research is carried out under random load conditions designed to simulate conditions encountered by aircraft under actual service environments. Loading programs such as Twist and Falstaff are employed and the influence of microstructure on fatigue crack propagation rates is being determined. High strength aluminum alloys in notched and riveted configurations are the principal subjects of investigation, but aramide reinforced aluminum laminate (ARALL), a development of Dutch aerospace research, is also being studied. Nowack is enthusiastic about the material because of its resistance to fatigue crack

growth, high tensile strength, and low weight (according to him, the use of the material in the fuselage of a 747 would result in a 50% weight saving). The department members are also studying the high temperature fatigue behavior of the titanium disk alloy 685.

#### ONERA

ONERA was founded in 1946 as an autonomous national aeronautical research organization. In 1963 it was incorporated in the Defense Ministry under the Directorate of Armament Research, Studies, and Techniques (DRET). The mission of ONERA is to conduct aerospace research of relevance to defense applications; it carries out both in-house and contract research programs in this respect. Currently, about 2,000 people are employed by ONERA at 6 research centers; approximately one-third of the workers are scientists and engineers. Its operating budget in 1981 was 540 million francs.

Research at ONERA is carried out in eight scientific departments: Systems, Aerodynamics, Large Testing Facilities, Structures, Energetics, General Physics, Materials, and Informatics. The Materials Department, headed by Dr. Paul Costa, consists of about 100 people and is at ONERA's main laboratories in Châtillon-sous-Bagneux, a suburb of Paris. The main activities of the department concern research on new materials and processes, evaluation of in-service performance of current existing materials, and development of materials characterization tools and techniques. Materials of importance to the aerospace industry, superalloys, lightweight alloys, and composites, are being investigated. Costa's assistant, Dr. R. Pichoir, and several members of the staff briefed the author on research programs in progress. Staff members were: Drs. T. Khan and M. Rabinovitch - superalloys, Drs. A. Walder, F. DuFlos, and J. Stohr - powder metallurgy, Dr. M. Duret - oxidation, Drs. R. Valle and B. Daigne - electron microscopy, and Dr. J. Bind - ceramics.

For several years research on superalloys at ONERA has concentrated on directionally solidified eutectic alloys. The alloys, with as much as 6 vol % TaC or NbC as the fiber reinforcement, were found to have good strength properties and would allow an 80°C gain in use temperature over classical superalloys. A typical life of 2,000 hours could be obtained at 1070°C and at a stress of 120 MPa, while 600-hour lives were obtained at 150 MPa. Transverse properties were somewhat lower, but satisfactory, and good creep and fatigue properties were obtained. Unfortunately, processing the alloys was difficult. The high processing temperatures ( $\sim 1,700^\circ\text{C}$ ) and slow growth rates ( $\sim 1.2$  cm/hr) combined with chemical and mechanical problems with molds all add up to make a difficult and expensive operation, and the commercial usefulness of the alloys is doubtful. ONERA has phased out its research on these materials, but it is attempting

to pass the experience gained in developing them to French industry.

Current superalloy research consists of studies of single crystal alloys and powder metallurgy processed alloys. For the most part, the single crystal activity has involved collaborative efforts with commercial firms in the development of new nickel base alloys. One phase of the work has been an investigation of the effect of high-temperature gradients during alloy growth on microporosity. The studies indicated that by adjusting the temperature gradient in alloys grown at rates of 80 cm/hr microporosity could be reduced to less than 0.1%, which is as much as four times lower than that normally found in material processed by standard industrial methods. The low porosity results in noticeable improvement in fatigue properties.

Powder metallurgy (P/M) processing of superalloys consists of studies of the effect of P/M processing on the properties of conventional nickel base alloys. The people engaged in the research make their own powder using the rotating electrode method. Powder preparation, classification, and handling is carried out within a class-10,000 clean room to minimize contamination. Kilogram quantities of 130- $\mu$ m-diameter powders are regularly produced for use in research. Consolidation is carried out by extrusion on a 250-ton press or by hot isostatic pressing. In addition to the work with conventional superalloy powders, research on rapidly solidified powders will soon begin. A conventional melt spinning apparatus has recently been built for this research and is now being debugged. Research with the unit will begin with a study of nickel-base brazing alloys and continue with investigations of more conventional superalloys.

Research on lightweight alloys at ONERA currently involves 7000 series aluminum alloys and Ti-6Al-4V and IMI 685. In the case of aluminum alloys, the effect of processing variables, such as quenching rates and thermomechanical treatments, on the fracture toughness of 7010 and 7050 alloys has been of particular interest and has been shown to influence fracture toughness values significantly. For example, slight variations in heat treatments have caused changes in  $K_{IC}$  of 50% or more. The microstructural causes of the changes are being investigated. Titanium alloy research focuses on the long-term stability of alloys such as IMI 685 at high temperatures and seeks to correlate changes in mechanical properties with thermally induced microstructural changes and changes due to long-term exposure to oxidizing atmospheres. Of particular interest is the ability to differentiate changes caused by the two effects in order to assess their relative importance. In addition to this work, research on powder metallurgy processed IMI 685 is being carried out. Powder for this research is produced in another clean room facility that duplicates the one used to produce superalloy powders.

Oxidation and hot corrosion research at ONERA concentrates on processes for applying protective coatings and the behavior of coatings under service conditions. Although some work on diffusion coatings of aluminide is in progress, most is on overlay coatings. Application techniques being studied include PVD, CVD, and sputtered coatings using a triode sputtering system. A low-pressure plasma spray facility will soon be available. For the most part, research is aimed at developing coatings and procedures for coating directionally solidified eutectic alloys and single crystal alloys. Studies are being made of the interdiffusion and reaction of coatings with substrates, diffusion barriers, and the effect of thermal cycling on coating integrity.

The use of ceramic materials for high-temperature heat exchanger or turbine applications has been of interest for a number of years, and several research programs are being conducted on ceramic materials. Much of the effort involves the characterization of commercially available ceramic fibers, the synthesis of ceramic fibers, and the development of ceramic-ceramic composites. The last-named project has involved experiments with composites of polycrystalline alumina matrices reinforced with about 40 vol % alumina fibers. These composites are made by infiltration of the fiber network with a suspension of micron sized alumina particles followed by a low-temperature sintering treatment. Despite the relatively low degree of cohesion between fibers and matrix, rupture strengths of 380 MPa at 800°C were achieved. In addition to research on ceramic composites, research on the high temperature application of bulk ceramics is taking place. For example, the use of bulk SiC for both heat exchanger tubes and gas turbine blades is being investigated. For the turbine blade application a test turbine is being made to permit testing of air-cooled SiC blades of elliptical cross section about 1.5 in. long at gas inlet temperatures up to 2,000°C and at speeds as high as 30,000 RPM. An intricate design using superalloy inserts to maintain compressive stresses in the ceramic blades is being investigated.

Besides its materials research efforts, the materials department at ONERA has been engaged in developing tools for extending materials analysis capabilities. The facilities are impressive, including a 1-MV electron microscope operated in conjunction with CNRS (University of Paris-Sud), and a secondary ion emission microprobe that is under development.

*P.A. Clarkin*  
ONR London

#### INTERNATIONAL POWDER METALLURGY CONFERENCE

An International Powder Metallurgy Conference was held on 21 to 25 June 1982 in

Florence, Italy, with participation from 32 countries. Approximately 100 papers were given in two concurrent oral sessions, and a small number were presented as posters.

The products of the powder metallurgy (P/M) industry cover a wide area of technology, ranging from inexpensive pressed and sintered parts to components for critical applications, e.g., for gas turbine engines. While the division into categories is not precise, the noncritical parts tend to be made by compaction and subsequent sintering of simple Fe or alloys with lower melting temperatures (e.g. Al and Cu), with substantial porosity remaining after fabrication. The critical components are typically made from highly alloyed metals, such as tool steels or superalloys and have no, or very low, residual porosity, as the consolidation process generally includes the imposition of pressure at elevated temperatures by such methods as hot isostatic pressing (HIP) or hot extrusion.

Other than for many critical, high performance applications, the use of P/M components is strongly cost limited. While the largest current market for P/M products is for noncritical applications, as in automobiles, the use of P/M components is under increasing pressure from other forming processes, related in part to the increased use of robotics.

P/M does have inherent advantages that will ensure its continued wide use. Most familiar is its ability to produce complex shapes with reduced forming and machining, leading to reduced costs and materials conservation. There are also opportunities for increased use of P/M in areas where the process is not just a less expensive substitute, most notably for the production of oxide dispersion strengthened (ODS) alloys or other such composites and for alloys made via rapid solidification technology (RST). RST can be used to produce parts, from very complex alloys, having a very fine microstructure and superior properties; in addition, such advantageous properties can often be achieved only via the P/M route.

Highlights of several selected papers relating to high performance P/M alloys are given below.

Several papers focused on oxide dispersion strengthened alloys. A paper entitled "Investigation of Structure and Properties of Dispersion Hardened Alloys Obtained at Different Velocities of Pressing" was presented by Dr.

Petr Vutjaz (Belorussian Powder Metallurgy Institute, Minsk, USSR). Vutjaz described a process in which Cu powder containing low Al levels was heated at 450°C to produce oxide coatings. The powder was subsequently heated in an inert atmosphere at 750°C. The powders were hydrostatically compressed and then extruded at various speeds and temperatures. Shock compression was also used; above 10,000 m/sec compaction speeds, additional hardening was observed. The oxide particles were typically ~200 Å in diameter with a 600 Å interparticle distance.

J.J. Huet, et al (France) described oxide dispersion strengthened ferritic stainless steels

having high damping capacity. The 13% Cr, 1.5% Mo alloys also contained 2 to 4% Ti. Titania ( $Ti_2O_3$ ) or yttria ( $Y_2O_3$ ) was added to the elementary metal powders which were first ball milled, then cold and hot compacted and finally hot extruded at 1050°C. The Ti improved the mechanical properties, while the fine dispersed oxide stabilized a fine grain size and prevented embrittlement. Tensile strengths of up to 900 MPa at 500°C were observed. For another alloy, a fatigue limit at 600°C of 250 MPa (one half of the UTS of this alloy at this temperature) was observed. The damping capacity of the ODS alloys at room temperature is similar to that of conventional competing materials; however, it is about three to five times higher at 600°C. Combined with the high fatigue strength, the alloys are thus of interest for special uses, e.g., as blades in gas turbines. Resistance to gaseous  $SO_2$  was suitable, with the alloys containing yttria superior to those containing only titania.

R.F. Singer and G.H. Gessinger (Brown-Boveri Research Center, Baden, Switzerland) reported on their work on MA 6000E, a superalloy strengthened by  $\gamma'$  precipitation and oxide ( $Y_2O_3$ ) dispersion. After milling, the powders were packed in steel cans, vacuum outgassed at 600°C, and then HIPed at 850 to 1250°C, 0.2 to 4 h, and 130 to 1790 MPa. HIP was investigated because it allows the production of larger ingots (and hence components) than does extrusion. However, the HIPed alloy did not readily recrystallize to the large elongated grains required for good high-temperature creep strength. Predeformation of the HIPed material led to a satisfactory recrystallization response for a suitably high strain rate and strain; creep behavior of this recrystallized material was similar to that of the extruded alloy.

M. Jeandin et al. (Ecole des Mines de Paris, Evry, France) reported on the use of liquid phase sintering at 1300°C, followed by HIP or forging, to densify Astroloy powder. While the microstructure could differ from that of directly HIPed material, the mechanical properties were similar. The fatigue behavior of the liquid phase materials was good; in particular, no crack initiation from ceramic particles was seen, leading to the hypothesis that the liquid phase might have reacted beneficially with the ceramic particles. Further studies with the purposeful addition of zirconia, alumina, and silica particles have not yet proven or disproven the effect.

G.H. Choghi (Ecole des Mines de Paris, Evry, France) discussed a low-carbon Astroloy produced by HIPing argon atomized powders (<177µm) at 1120 and at 1180°C. Samples compacted at 1180°C had better mechanical behavior, which was ascribed to better adhesion. Appropriate cooling was found to give wavy grain boundaries and was also associated with increased flow stress and ductility. A fine dispersion of secondary carbides was achieved by a two-stage aging treatment (650°C/16h+750°C/8h); tensile and creep behavior at 650°C was improved.

Representatives of Leybold-Heraeus presented four papers relating to equipment and techniques for powder production by atomization and for subsequent powder handling before consolidation for high-quality powders, e.g., Ni and Ti alloys for aerospace applications. W. Pietsch (Leybold-Heraeus, Hanau, FRG) authored a paper reviewing the entire field. A paper by H. Stephan et al. (Leybold-Heraeus, Hanau, FRG) described the operation of equipment built by their firm for vacuum degassing of the powder followed by encapsulation of the powder in a sealed container suitable for subsequent consolidation. W. Pietsch et al. (Leybold-Heraeus, Hanau, FRG) described two variants of EBRD (Electronic Beam Rotating Disc) equipment produced by Leybold-Heraeus that are especially suited for producing powders of reactive (e.g. Ti) or refractory (e.g. Ta) alloys. An electron beam, or alternatively a plasma gun or an electric arc, is used to melt the tip of an ingot. Either the ingot can be rotated rapidly such that droplets are thrown from the surface, or drops of the molten metal can be allowed to fall onto a rapidly rotating cup so as to cause fragmentation of the liquid. However, particle sizes are much larger than those that can be produced readily by gas atomization techniques, so that most rapid solidification effects cannot be achieved. Perhaps the most interesting paper of this group was by R. Ruthardt and related to ultrasonic atomization (not to be confused with the ultrasonic gas atomization practiced by others). In the process, a thin layer of the molten metal flows onto a solid substrate surface that vibrates ultrasonically. So far, a limitation on the mechanical strength of the substrate has restricted the melting temperature of alloys that can be processed to under 1000°C. One advantage is that the droplets leave the surface slowly, so that only a small chamber is necessary, making capital costs less than gas atomization. Particle size depends on the ultrasonic frequency and the properties of the liquid metal. At 10<sup>4</sup> Hz, a mean particle size of 40 μm is achieved for Ag; finer sizes will be possible if operation at higher frequencies is achieved.

*D.E. Polk*

ONR Arlington

## OCEAN SCIENCES

### UNDERWATER ACOUSTIC TRANSDUCER MANUFACTURE IN FRANCE

The author was invited by Mr. Claude C. Leroy, Ingénieur de Recherches and Chef de Service Propagation at SINTRA-ALCATEL Department (DSM), to visit the organization's transducer plant at Aubange, about 20 km east

of Marseille. SINTRA-ALCATEL was one of four divisions of the CGE group that moved from CIT in a corporate reshuffle about 4 years ago. (CGE is the Compagnie Générale d'Electricité, CIT stands for Compagnie Industrielle des Téléphones, SINTRA for Société Industrielle des Nouvelles Techniques Radioélectriques, and ALCATEL for Alsacienne Construction Atomique et Télécommunications). On the same site is a manufacturing facility of the Pons Company, another subsidiary of CGE (Pons was the name of the original founder). The SINTRA-ALCATEL group is concerned with research and development for underwater sound, and Pons manufactures transducers to specification. Until fairly recently all transducer development was done by the French naval facility at Le Brusc (see ONRL report R-3-79, "Developments in Acoustic Transduction in Europe" by R.J. Bobber, AD-A073 406) but in the last 3 or 4 years some of the work has been contracted out, and in addition ALCATEL has been establishing its own team for commercial applications.

The visit was informal and the discussions were limited, but there was a display of products about which I had the opportunity to ask questions. In addition to Leory, who had spent some time at SACLANTCEN, I met Mr. Dauvergne and Mme. Adda, engineers. In the display was an 18-element transducer array about 15 cm in diameter operating at about 27 kHz. The tonpilz-type elements were arranged in a hexagonal grid in two concentric circles of 6 and 12, but without an element at the center. I learned that it was for a sounding repeater, designed to sit on the ocean floor and transmit upwards when interrogated by a ping from a surface vessel. I also saw some response patterns, with the first sidelobes down only about 10 db, as might be expected. There were a number of individual tonpilz elements, the smallest designed for operation at 80 kHz, though it is expected that higher frequencies will be necessary for parametric arrays. My informants were particularly proud of a 3 kHz high-power transmitter, though I do not recall mention of the actual number for the power. There was a ring transducer, designed to operate at 3 kHz, which seemed to be made of a single piece of ceramic but had stripes for the electrodes (presumably polarized appropriately). This was installed in a standard 21-in. torpedo head, with a polyurethane window; some problems were encountered in molding the window. The French transducer ceramic has a lower Curie point than that used in the United States. There was also a smaller ceramic ring, unmounted, about 12 cm in diameter, wound with glass fiber thread for prestress.

I was given a tour of the Pons ceramic manufacturing plant by Leroy and Mr. Bellamy, who is in charge of operations. The plant works entirely to outside specifications (mostly from the French Navy Laboratory at Le Brusc) and has no development staff of its own. In manufacturing their powder products, the Pons workers go through the complete process of

mixing, sintering, pressing, grinding to shape, firing, silvering, polarizing, and finally testing for activity and loss factor. Most of the production seemed to be of discs about 5 cm in diameter and about 6 mm thick, intended for low-frequency (about 3 khz) tonpilz elements for cylindrical sonar arrays. The elements have the usual head and tail masses and four tie rods outside the active ceramic. Short runs and "specials", including some for SINTRA, are also made. I was shown some discs about 8 mm in diameter and 0.2 mm thick intended for flexural transducers, but I did not see any actual assembly operations. In answer to a query, I was told that an Araldite compound is used for the cement joints. For some repair and replacement work they are still using Adenosine Diphosphate (ADP), and even Rochelle salt!

There was a tank about 15 m diameter and 7 m deep, unlined, in which tests were performed by the usual pulse technique. The apparatus seemed to be an assembly of parts from various manufactures, including Hewlett Packard, but did not seem to be well automated.

Pons is said to be one of only two transducer manufactures in France. The other is a part of the Thompson-CSF group at Cagnes-sur-Mer.

*G.L. Wilson*

Pennsylvania State University

## PHYSICS

### Solitons '82: The Scott Russell Centenary Conference: Part I

Solitons, or solitary waves, are localized nonlinear waves with unusual properties that distinguish them from the familiar linear waves. Soliton amplitudes are always positive so that, in the case of water waves, they appear as singular bumps with no trough. The solitary wave speed exceeds that of the associated linear waves by an amount proportional to its amplitude. Thus, a train of solitons would be observed in order of decreasing size. Solitons in collision interact nonlinearly and, on separation, recover their precollision shapes.

The first documented observation of a solitary water wave was by John Scott Russell, an Edinburgh naval architect and engineer who made the following observation in 1834:

"I was observing the motion of a boat which was rapidly drawn along a narrow channel by a pair of horses, when the boat suddenly stopped--not so the mass of water in the channel which it had put in motion; it accumulated round the prow of the vessel in a state of violent agitation, then suddenly leaving it behind, rolled forward with great velocity assuming the form of a large solitary elevation,

a rounded, smooth and well-defined heap of water, which continued its course along the channel apparently without change of form or diminution of speed. I followed it on horse-back, and overtook it still rolling on at a rate of some eight or nine miles an hour, preserving its figure some thirty feet long and a foot to a foot and a half in height. Its height gradually diminished and after a chase of one or two miles I lost it in the windings of the channel."

This August, about 140 scientists from around the world met at the site of Russell's observation, the Riccarton Campus of Heriot-Watt University, to pay tribute to Russell on the 100th anniversary of his death and to discuss progress in soliton research. Advances in the mathematical theory of solitons and applications in areas spanning DNA molecular dynamics, general relativity of the Big Bang, and nearly everything in between were presented in some 60 papers evenly divided between 1-hour talks and poster sessions. The conference and workshop following were organized by Dr. J. C. Eilbeck of Heriot-Watt and Dr. A. C. Scott of the Los Alamos National Laboratory.

The mathematics talks described the properties and solution techniques of the large class of nonlinear, integrodifferential equations that admit solitonic solutions, their group-algebra representation, and their extension to multiple spatial dimensions. In this report, the applications of soliton theory to physics rather than the mathematical methods are stressed. In the first part, applications to hydrodynamics and electronics are presented. The second part will appear in the October ESN and discuss applications to condensed-matter and fundamental physics.

### INTRODUCTORY CONCEPTS

In many current applications, the soliton is not a physical displacement of material but is a more subtle quantity such as a region of phase change in statistical mechanics, a crystal domain boundary in materials science, or a disturbance in electron-spin orientation in a ferromagnet. The mathematical theory of solitary waves was first developed for water waves in a shallow channel by Korteweg and de Vries in 1895. Development of soliton theory in terms of hydrodynamics therefore represents a natural starting point and provides results that are most easily understood. Dr. A.R. Osborne of the Istituto di Cosmo-Geofisica, Turin, Italy, provided some of the historical background discussed in this section and an analysis of internal soliton measurements in the Andaman Sea described in the next.

The Korteweg-de Vries (KdV) equation for propagation of solitary surface waves is

$$W_t + C_0 W_x + \alpha W W_x + \gamma W_{xxx} = 0 \quad (1)$$

where  $W(x,t)$  is the wave amplitude as a function of the horizontal distance  $x$  along the channel and the time  $t$ . The subscripts  $x$  and  $t$  refer to partial derivatives of  $W$  and the

coefficients are defined by

$$C_0^2 = gh; \alpha = 3C_0/2h; \gamma = C_0 h^2/6, \quad (2)$$

where  $h$  is the water depth,  $g$  is the acceleration due to gravity, and  $C_0$  is the usual linear-wave phase velocity for the medium. A stable soliton solution of Eq. (1) arises because of a balance between the nonlinear ( $WW_x$ ) and dispersive ( $W_{xxx}$ ) terms and takes the form

$$W = W_0 \operatorname{sech}^2[(x - Ct)/L]. \quad (3)$$

Here  $W_0$  is the maximum amplitude,  $C = C_0(1 + W_0/2h)$  is the amplitude-dependent wave speed, and  $L = (4h^3/3W_0)^{1/2}$  is the characteristic length of the disturbance.

Martin Kruskal (Princeton Univ.) described the modern rediscovery of solitons in an invited talk that began the conference. Difficulties with obtaining analytic solutions of nonlinear equations, the lack of large-scale computers, and the rarity of observed solitary waves in nature were responsible for waning interest in solitons until 1965 when N.J. Zabusky and M.K. Kruskal (*Phys. Rev. Lett.* 15, p240, [1965]) performed a computer calculation that solved the KdV equation for two solitary waves in collision. By that time, the importance of KdV to plasma magnetohydrodynamics, waves in anharmonic crystals, and the dynamics of weakly nonlinear particle chains (the Fermi, Pasta, Ulam problem) had been recognized. The numerical work demonstrated the remarkable stability of solitons and their ability to preserve their identity through numerous interactions.

The computer experiment stimulated the development of a new analytic technique for the solution of KdV by Kruskal and co-workers (C.S. Gardner, et al., *Phys. Rev. Lett.* 19, p1095, [1967]). In that work, the solution to KdV in the form

$$U_t - 6UU_x + U_{xxx} = 0 \quad (4)$$

was shown to be related to the linear Schrödinger eigenvalue equation of quantum mechanics

$$\psi_{xx} - (U - \lambda)\psi = 0. \quad (5)$$

Here,  $U(x, t)$  plays the role of a scattering potential, and  $\psi(x, t)$  and  $\lambda(t)$  depend parametrically on  $t$ . Under certain conditions, solving for  $\psi$  by determining the evolution of scattering amplitudes provides sufficient information to reconstruct  $U(x, t)$ . The usual quantum mechanical solution technique is therefore applied in reverse so that the method of solution for  $U$  is called the inverse scattering transform (IST). A number of the mathematical talks at the conference demonstrated that the other physically important nonlinear equations with solitary-wave properties can now be solved by a suitable extension of IST.

The solutions obtained in the 1967 paper

documented the initial conditions under which one or more solitons would evolve, determined their amplitude and velocity, and predicted the existence of an associated dispersive linear wave train. Because of the smaller speed of the linear waves, they trail the solitary-wave packet by a separation that increases with time. This separation and those between individual solitons of different amplitude within the packet provide a means of determining the location of the initial disturbance creating the waves by extrapolation back to zero separation.



Figure 1

#### WATER WAVES AND HYDRODYNAMICS.

Osborne reported on analyses of large-amplitude, long internal waves and associated surface waves discovered during a 4-month measurement program conducted by Exxon in the southern Andaman Sea. The internal waves arrived in packets of five or six and were spaced about 12 hours and 26 minutes apart as measured by temperature and current-velocity detectors at various depths up to 254 m. The timing indicated a tidal origin for the internal solitons. The internal waves were accompanied by a rip that altered the reflectivity of the ocean surface. A subsequent search of satellite images revealed the large-scale surface structure of the waves. Figure 1 shows an image of the Andaman Sea taken during the Apollo-Soyuz mission. Crests as long as 150 km separated by about 15 km were observed. Wave velocities

were plotted as a function of wave amplitude and agreement with the predictions of the KdV equation was obtained. From the observed spacing of the waves within each packet, the source of the initial disturbance was traced to an island chain about 300 km from the observation region.

Osborne has spent the last 2 years developing a computer code to solve Eq.(5) for any given potential  $U$ . The procedure is the nonlinear analogue of the Fourier transform and predicts the soliton eigenmodes, the continuous linear spectrum of dispersive waves, and the associated phase information. The code was tested using a square-wave potential, as that case can be solved exactly by analytical means. The computed continuum spectrum was identical to the linear Fourier spectrum for small amplitude waves but showed substantial deviations when the ratio of wave height to water depth ( $\epsilon$ ) exceeded 0.01. At such amplitudes and below, single-soliton creation was predicted. Multiple solitons were predicted for larger values of  $\epsilon$ , reaching six by  $\epsilon=0.5$ . Following the test runs, the experimental wave amplitude vs. time data were used for  $U$ . In addition to a multiple-soliton spectrum with the correct velocity distribution, the nonlinear transform predicted a continuum spectrum that had not been observed previous to the calculation. The correctness of both the soliton interpretation for the waves and the nonlinear-transform code is indicated by the subsequent discovery of the linear-wave train at the predicted location behind the soliton packet.

On a much smaller scale, Dr. A. Korpel (Univ. of Iowa) reported on preliminary experiments with nonlinear waves in a small ripple tank. The waves were produced with a piston paddle moving continuously in a sinusoid and were diagnosed by images projected through a modified overhead projector on which the tank was mounted. Two types of nonlinear waves were produced. At low paddle frequencies, the nonlinear wave phase velocity had an additive term proportional to the square of the amplitude. At higher frequencies, the quadratic term became subtractive. As the wave amplitude is always largest at the center of the paddle, the low-frequency waves were observed to defocus as they propagated while the high frequency waves focused. Strong subharmonic generation through a three-wave interaction was also observed. Solitons were not produced in the experiments because the waves were continuously generated. Korpel hopes to create true solitary waves as predicted from the nonlinear Schrödinger equation by pulsing the paddle for a few oscillations.

An interesting paper by Dr. Ogordnikov (Novosibirsk, USSR) was made available by Prof. Kulish (USSR Academy of Sciences) on the subject of solitary waves in a structured medium. Ogordnikov considered a fluid in which spherically symmetric bubbles were uniformly dispersed. Variation in void fraction (the fraction of the volume occupied by the

bubbles) and the bubble radius provided the properties of the medium needed to support solitary waves. The structured medium is characterized by two sound speeds, the pure-liquid sound speed for high-frequency disturbances and the equilibrium sound speed for the fluid-bubble mixture, which can be much less. As the void fraction is increased from zero, the equilibrium speed can decrease from 1500 m/s to 50 m/s for a few percent concentration. Thus, the medium will be highly dispersive. For a fixed void fraction, the sound speed will vary nonlinearly from the equilibrium to pure-liquid value as the wave amplitude is increased. Both the dispersive and nonlinear requirements for solitary waves are therefore present.

Ogordnikov solved the equations of hydrodynamics and an evolution equation for the characteristic bubble radius to obtain an integrodifferential equation for pressure waves. In the limit of small frequencies compared to the characteristic bubble-pulsation frequency, the KdV equation was obtained. In the opposite limit, the Klein-Gordon equation was obtained. Unlike KdV, solitary waves of this equation have a velocity that varies nonlinearly with amplitude, suffer energy loss during interactions, and change the medium following passage. Results of the analysis were compared with two experiments conducted by N.V. Malykh and V.E. Nakoryakov.

#### ELECTRONICS AND OPTICAL COMMUNICATIONS.

The transmission of optical solitons in monomode glass fibers was discussed by Yuji Kodama (Bell Labs.). Such waves have potential application to high bit-rate transmission as they can propagate without distortion even in the presence of group dispersion. A nonlinear change in the fiber dielectric constant (the Kerr effect)

$$n = n_0(\lambda) + n_2 E^2 \quad (6)$$

provides the required compensation for group dispersion. In Eq.(6), the light wavelength  $\lambda$  is chosen to be 1.27  $\mu\text{m}$  for minimum dispersion and  $E$  is the sum of the amplitudes of the soliton and continuous wave electric-field strengths. The strength of the nonlinear term is given by

$$n_2 = 1.2 \times 10^{-22} (\text{m/V})^2 \text{ for SiO}_2.$$

Using Eq. (6) in the Maxwell equations, neglecting losses and higher-order dispersion leads to

$$iq_t + \frac{1}{2}q_{xx} + |q|^2 q = 0 \quad (7)$$

which is the nonlinear Schrödinger equation for the optical signal envelope function. The IST method can be used to solve Eq. (7) for one soliton with an associated continuous wave. Neglecting the complex phase, the form of the soliton in space is

$$u \sim \text{nsech}(\eta x) \quad (8)$$

where  $q=u+f$  and  $f$  is the continuous wave. Using a perturbation analysis for which the amplitude of  $f$ ,  $E_0$ , is much less than  $\eta$ , Kodama showed that injecting a properly phased continuous wave could increase the soliton height by  $\pi E_0$ , an amount  $\pi$  times larger than the linear superposition. From the form of Eq. (8), the increased amplitude is accompanied by a pulse narrowing. The numerical example of an 11.4-ps pulse width with losses of 0.2 dB/km was considered. By injecting a continuous wave of  $1.8 \times 10^5$  V/m every 9.4 km, a soliton power of 105 mW could be maintained. Although sophisticated technology is required for phase detection and matching at the injector locations, the long 10-km spacing makes the technique a potential candidate to replace conventional repeaters.

Dr. P.L. Christiansen (Technical Univ. of Denmark) described a detailed numerical study of a soliton model for the Josephson tunnel junction and compared the analysis with experimental measurements. The Josephson junction considered consists of two superconducting metal layers separated by an insulating oxide strip that is thin enough to permit quantum-mechanical tunneling of electrons. The tunneling supercurrent per unit length and voltage drop across the insulator are described by

$$j = j_0 \sin \phi ; \quad \frac{2eV}{h} = \phi_t, \quad (9)$$

where  $\phi(x,t)$  is the phase difference in the order parameters of the two superconductors (a measure of magnetic flux) and  $x$  is measured along the strip. When Eq. (9) is combined with the Maxwell equations

$$\beta \phi_{xxt} + \phi_{xx} - \phi_{tt} - \alpha \phi_t = \sin \phi - \gamma, \quad (10)$$

where  $x$  and  $t$  are now normalized to the Josephson length and the inverse of the Josephson plasma frequency,  $\alpha$  and  $\beta$  are determined from the junction impedance, inductance, and capacitance (P.S. Lomdahl, O.H. Suerensen, and P.L. Christiansen, Phys. Rev. B 25, p5737, [1982]) and  $\gamma$  is the ratio of externally applied bias current to  $j_0$ .

Equation (10), the Sine-Gordon equation, has single and multiple soliton solutions. The solitons move in  $x$  and are accompanied by a time-varying voltage pulse. The dc current-voltage characteristic exhibits branches known as zero-field steps (ZFS). The Nth ZFS corresponds to the motion of  $N$  solitons moving back and forth along the junction in an electromagnetic-wave transit time.

Numerical solution of Eq. (10) for different ratios of junction length to Josephson length accurately explains experimental observations. Figure 2 compares the calculated (circles) and experimental (solid lines) dc voltage vs bias current characteristic for the first three ZFS's.

Christiansen stated that the existence of such bunched-soliton configurations is crucial to an understanding of the internal dynamics of Josephson junctions.

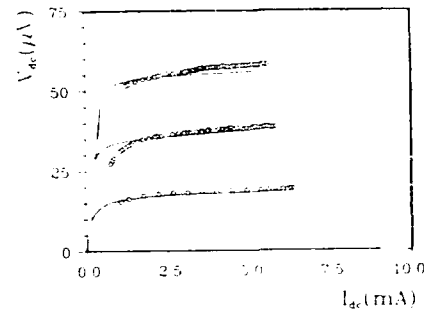


FIGURE 2

Dr. T. A. Minelli (Istituto di Fisica dell'Universita-Sezione INFN, Padova, Italy) discussed his research on the use of conservation laws to describe soliton fission and tunneling in nonlinear systems with discontinuities. Although his immediate interest is tunneling in quantum mechanical systems via the nonlinear Schrödinger equation, he has treated classical transmission lines with nonlinear elements as an example. Specifically, he considered soliton penetration across a sudden change in line characteristics for two dispersive and nonlinear half lines. Each half line consisted of parallel inductance and capacity elements  $L\Delta x$  and  $C_s/\Delta x$  with the nonlinearity provided by the voltage dependence of shunt capacitor elements  $C\Delta x$  where  $C = C_0 + C_N V$ . The values of  $C$ ,  $C_s$ , and  $L$  can change discontinuously at the junction of the two half lines.

Propagation of a voltage pulse in each half line is described by the KdV equation. The shape of the pulse propagating towards the discontinuity in the injection half is then

$$V = A \operatorname{sech}^2 \left( \frac{x - x_0 - vt}{1} \right), \quad (11)$$

where

$$1 = (6C_{s1}/AC_{N1})^{1/2}; \quad v = \left( 1 + \frac{C_{N1}A}{3C_{o1}} \right) / (L_1C_{o1})^{1/2}. \quad (12)$$

At the discontinuity, the incident soliton fissions into a transmitted packet, a reflected packet, and scattered continuum radiation.

Minelli compared the results of numerical simulation with transmitted and reflected amplitudes determined from conservation of total charge and energy in the two half lines. For the case of  $A=2$  V,  $L_1=10$  nH,  $L_2=2L_1$ ,  $C_{s1}=C_{s2}=236$  pF,  $C_{o1}=C_{o2}=160$  pF,  $C_{N1}=C_{N2}=1.77$  nF/V, and 160 computational cells, 4% agreement between computation and conservation laws was obtained.



for the evolved soliton in the second half of the line. Each half line was 100 ns long and the half width of the injected pulse was 13 ns. Minelli expressed the belief that the approximate results from conservation laws represent time-saving initial conditions for numerical calculations of nonlinear equations with discontinuities.

*D. Mosher*

ONR London

#### SURFACE-RELATED PHYSICS AT THE UNIVERSITY OF LANCASTER, UK

The University of Lancaster, UK, was granted a Royal Charter in 1964 as one of Britain's modern universities, and physics research there has been observed and reported on from time to time by liaison scientists at ONR London (R.A. Hein, "Some Low-Temperature Research at The Universities of St. Andrew, Lancaster, and Nottingham," ONRL Report 36-71: 7-13; T.A. Kitchens, "Low-and Very-Low-Temperature Physics and The University of Lancaster," ESN 30-7:326 [1976]). Among the activities described were ultra-low-temperature investigations of helium at millidegree temperatures and studies of superconducting tunneling, ultrasonic attenuation, and superconducting materials.

Today the Department of Physics has an academic staff of 31 including 3 professors: R.H. Tredgold, head of the department, whose main research interest is Langmuir-Blodgett films; A.B. Clegg, nuclear physics, involved with elementary particle research; and W.M. Fairbairn, theoretical physics.

As a reflection of previous research interests in the department, a new dilution refrigerator operates continuously down to 3.5 mK° in conjunction with further cooling being achieved with a nuclear demagnetization cryostat. The properties of very pure <sup>4</sup>He are currently being investigated. The storage of essentially loss-free ultracold neutrons in pure superfluid <sup>4</sup>He is being studied and J.K. Wigmore is continuing research in ultrasonics. A new development is the detection and analysis of phonon echoes from the interaction of coupled ultrasonic waves and (microwave) photon pulses, both produced at the same angular frequency, within a non-centrosymmetric crystal, such as lithium niobate (LiNbO<sub>3</sub>), immersed in liquid helium at 1.25°K (see D.J. Meredith, J.A. Pritchard and J.K. Wigmore, *J. de Physique*, C6, 42, 870-2 [1981]). An interesting aspect of the work is that, in some cases, phonon echoes are apparently traceable to impurity defect structures that are strongly coupled to the lattice phonons, so the echoes may provide sensitive information about the crystal defect structure.

Surfaces, defect-free and defect-full, are currently an important subject of research at

Lancaster, both because of the basic physics associated with understanding the nature of mechanical adhesion processes and making surface energy measurements and because of the important role surfaces (and interfaces) play in physical electronics studies and their applications to electrical industries. The various surface studies by individual researchers at Lancaster, however, from the topic of mached metallic microprobes for measuring adhesive friction to that of insulating monolayers of amphiphilic molecules on suitable electronic substrates, have no common framework. The activities seem to have resulted in an unplanned way which might prove to be fortuitous for the eventual development of collaborative research.

H.M. Pollock has been involved with the design of an ultra-low-load hardness tester (see D. Newey, M.A. Wilkins and H.M. Pollock, *J. Phys. E. Sci. Instrum.*, 15, 119-22 [1981]). A newly designed apparatus is intended to operate

within an ultrahigh vacuum chamber ( $10^{-10}$  torr) for studies of friction and of adhesion under conditions in which the contact area is so small say  $10^{-14}$  m<sup>2</sup>, that surface energy (or surface stress tensor) considerations are thought to play a major role in determining the nature of the indentation measurements.

One of the chief reasons the foregoing activity was initiated was the historical proposal that the macroscopic friction forces between bodies in contact can be attributed to the intense interaction of micro-asperities on the body surfaces. In this frame of reference, the proposed ultra-low-load hardness tester with a (field emission) needle point is visualized to model a single asperity experiment. Loads as small as 100 nN are measurably applied electrostatically, and electrical resistance measurements are made at currents less than 1  $\mu$ A to specify the contact area. The needle tip is examined before and after indentation by field emission imaging. The indented surface is examined, for example, by scanning electron microscopy and Auger electron spectroscopy methods.

The total load, indenter size, and indentation depth have been scaled down in the experiment so that the normal, appreciable deformation and fracture events that are measured in macro-hardness experiments can be measured on an ultrafine scale, with the additional consideration that surface energy or stress (capillarity) effects are imagined to be significant. (The sophisticated instrumentation and testing procedures that are involved in this activity would themselves provide an interesting research topic.) In high vacuum, the indenter adheres to the indented surface so that by reversing the applied force, the force required to separate the surfaces can be measured. By measurement of the force and contact radius, it should be possible to determine the Dupré adhesion energy,  $\Delta\gamma$ . The work of adhesion

per unit area of contact,  $\Delta\gamma$ , is specified, also, in terms of the energies of the two solid-vacuum interfaces,  $\gamma_1$  and  $\gamma_2$ , and of the solid-solid interface,  $\gamma_{12}$ , as  $\Delta\gamma = \gamma_1 + \gamma_2 - \gamma_{12}$ . For brittle materials, the separation process can be analyzed on the micro-scale on a fracture mechanics basis, and then the stress intensity for cracking is involved with its own connection to surface energy and "ultra-local" plastic work (see "A Study of Metallic Deformation, Adhesion and Friction at the Thousand-Angstrom Level," H.M. Pollock and S.K. Roy Chowdhury, Microscopic Aspects of Adhesion and Lubrication, J.M. Georges (Editor), Elsevier Publ., Amsterdam, 1982, p.253-62).

In July, 1982, the Institute of Physics Tribology Group, chaired by Prof. D. Tabor, held a half-day meeting at the University of Lancaster on "The Mechanics of Solid-Solid Adhesion". K. Kendall (ICI Mond Division) spoke about the role of adhesive energies in surface coatings, adhesive joints, and composite materials. J.A. Greenwood (Cambridge Univ.) discussed the mechanics of adhesive contact, and M.P. Seah (National Physical Laboratory Division of Materials Applications) described the effect of impurity segregation on interfacial fracture. Some 60 persons, slightly more than half of whom were from universities and polytechnics, were involved. Details of the meeting results can be obtained from H.M. Pollock, Department of Physics, University of Lancaster, Lancaster LA1 4YB.

Recently, the ultra-microhardness testing method has been applied at Lancaster to assessing the submicron depth strength properties of nitrogen- and titanium-implanted iron and steel materials relative to the effect of ion implantation on their wear resistance. Increased hardness and improved wear resistance were measured at a critical dose of  $10^{17}$  ions/cm<sup>2</sup> for nitrogen. An increased hardness was measured for the Ti-implanted iron, and the result matched the previous measurement of improved microabrasive wear properties for the material.

The foregoing ion implantation and hardness testing activities might be connected, eventually, with work the Department of Physics is doing on ion implantation for electrical-properties research in the area of physical electronics. For example, I.J. Saunders has been conducting research on isotopic bombardment with hydrogen and the stability of resistivity that can be produced in  $n^+$  GaAs for device isolation. This has led to a patent involving the use of deuteron bombardment to improve the efficiency and reliability of devices. Saunders is also involved in the growth of crystals such as lithium tetraborate ( $\text{Li}_2\text{B}_4\text{O}_7$ ), for thermoluminescence dosimeter applications.

R.A. Collins is using ion implantation to overcome thermal diffusion processes in micro-electronic devices and to study the oxidation of silicon and the oxidation and corrosion of a

variety of metals, including chromium. Improved semiconductor-metal contacts might be made with the assistance of ion implantation. Radiation damage is also being studied. Rutherford backscattering and nuclear reaction analysis are used for analytical determination of impurity concentrations and of oxygen uptake.

B.K. Jones is doing research on the detection of low-frequency noise as a tool for determining the presence of electronic states at the silicon surfaces of MOS (Metal-Oxide-Semiconductor) devices. At low frequencies, the reciprocal-frequency dependent noise contribution to the resistance is attributed for a number of materials including thin metallic films, sintered barium titanates, and granular carbon, to the interfaces between the grains. The grain boundaries are traps for the electrical charges, and small fluctuations in the number of charges trapped cause significant changes in the electrical resistivity. In a recent study of several types of silicon field-effect transistors, trapping processes at the oxide interface and at the depletion layer boundary of the channel for current flow were found to be important sources of noise (see B.K. Jones, *J. Phys. D: Applied Physics* **14**, 471-90 [1980]).

A final surface-related topic of research is that of Langmuir-Blodgett films. The films are being studied by R.H. Tredgold for semiconductor electronic device applications and for biophysical purposes relating to the transport of electrical charges in cellular tissues, especially nerve fibers. The insulating films are monolayers or multilayers of amphiphilic molecules put onto the surface of a substrate material one molecular layer at a time by a careful dipping process within a (Langmuir-Blodgett) trough providing a constant surface pressure during the film deposition. Exceptionally thin insulating films of controlled thickness, 1-20 nm thick depending on the molecular dimensions, and of excellent quality, can be deposited in this way. The efficiency of CdTe photovoltaic devices can be improved appreciably, for example, by using a monolayer of stearic acid between the semiconductor and the gold electrode. Films on GaP are being studied. Pre-formed polymer films and post-polymerized films have been used. Chlorophyll-a has been deposited between aluminum and gold electrodes to study the DC photoconductivity and photovoltaic effect. The physics of the electrical properties associated with the films as well as the determination of their internal structure is an interesting subject of investigation. A recent related paper is by R.H. Tredgold and R. Jones, "Schottky-barrier diodes incorporating Langmuir-film interfacial monolayers", *IEE J. Solid State and Electron Devices*, **128**, 202-6 (December, 1981).

R.W. Armstrong

ONR London

## STATISTICS

### PRACTICAL BAYESIAN STATISTICS

Bayes' formula is an elementary result in probability theory. If A and B are events with positive probability then

$$P(A \cap B) = P(A|B) \cdot P(B) = P(B|A) \cdot P(A)$$

from which Bayes' formula follows:

$$P(A|B) = P(B|A) \cdot P(A) / P(B).$$

We observe that Bayes' formula is nothing more than a simple computation. Nevertheless, a rather general body of techniques, called Bayesian Statistics, which are more or less related to the formula, has evolved in the applications of probability theory and has given rise to some controversy in contemporary science. As the formula is a trivial consequence of the probability axioms, any disagreement must of necessity lie in the applications of the formula and in the interpretation of the results.

One common application of Bayes' formula involves situations like the following: Suppose it is known that data to be observed in a sequence of experiments will be drawn from one of two populations,  $\theta_1$  and  $\theta_2$ . Suppose the population to be sampled is itself drawn at random, so that the population label can be considered to be a random variable  $\theta$  with possible values  $\theta_1$  and  $\theta_2$ . The experimenter may initially know (or be willing to assign) the probabilities  $P(\theta=\theta_1)$  and  $P(\theta=\theta_2)$ . When the data (say, D) have been observed, they generally contain information about the parent population. Thus, after experimentation, the experimenter should update his prior probabilities  $P(\theta=\theta_i)$  to the posterior values  $P(\theta=\theta_i|D)$ . The posterior probabilities would then contain the information appropriate for making inferences about the "state of nature" (value of  $\theta$ ) and for making predictions, such as future data values.

Bayes' formula can be used to compute the posterior probabilities in our simple example. Thus,

$$P(\theta=\theta_1|D) = P(D|\theta=\theta_1) \cdot P(\theta=\theta_1) / P(D),$$

where

$P(D) = P(D|\theta=\theta_1) \cdot P(\theta=\theta_1) + P(D|\theta=\theta_2) \cdot P(\theta=\theta_2)$ . If one uses odds, rather than probabilities, this takes an especially appealing form. To say that the odds in favor of some event A are a to one means that  $P(A) = a/(a+1)$ , from which  $a = P(A)/P(\bar{A})$ . If one uses Bayes' formula to express the numerator and denominator of the posterior odds in favor of the choice of population  $\theta_1$ , the result is

$$\frac{P(\theta=\theta_1|D)}{P(\theta=\theta_2|D)} = \frac{P(\theta=\theta_1)}{P(\theta=\theta_2)} \cdot \frac{P(D|\theta=\theta_1)}{P(D|\theta=\theta_2)}.$$

This can be stated verbally as follows: "The posterior odds equals the prior odds multiplied by the likelihood ratio."

The process characterizing a Bayesian model is the updating of a prior distribution to form a posterior distribution that takes into account information contained in data (or information obtained in any other form, for that matter). Some statisticians believe that this is the only reasonable approach to use in statistical applications; they call themselves Bayesians, and (in their more charitable moments) they call statisticians not insisting on this approach frequentists or classicists, because a large fraction of classical statistics (including estimation, hypothesis testing, and confidence interval estimation) falls outside the Bayesian framework. The author believes most frequentists do not feel there is a dichotomy requiring the statistician to declare allegiance to either the Bayesian or the classical camp. Apparently, however, many statisticians calling themselves Bayesians believe there are no circumstances in which a non-Bayesian model should be used in practice.

One difficulty that sometimes arises in the use of Bayesian models is the determination of an appropriate prior distribution. Such distribution is supposed to contain the knowledge about the state of nature at some point in time prior to experimentation. Some people believe the problem of determining a prior is so difficult that Bayesian methods are primarily of theoretical interest and are not really useful in practical applications. That this is far from the truth was underscored in a recent international conference, Practical Bayesian Statistics, attended by the author. The conference was sponsored by the Institute of Statisticians (UK) and was held at St. John's College, Cambridge. It was attended by approximately 150 statisticians from more than a dozen European countries. Some of the applications presented in a small sample of the more than 50 papers presented at the conference are described in what follows.

A paper entitled "Bayesian Methods Applied to Road Accident Blackspot Studies" was presented by C. Abbess (Middlesex Polytechnic, UK). Blackspots are sections of roadway that are presumably especially hazardous. The paper was concerned primarily with a "regression to mean effect" in accident rates observed at a location designated as a blackspot. The effect is caused by the way sections of roadway become classified as blackspots. Thus, if a relatively large number of accidents are observed at a section of roadway during some time period, local highway authorities are likely to designate it as a blackspot. There will be a tendency for lower rates of accidents to occur in the section in subsequent periods, even if no change in the mean accident rate has occurred. (If some safety measures have been taken by the authorities, a subsequent drop in accident rates may be interpreted as successful treatment of the problem, even though perhaps no

actual change in mean rate has occurred.) Abbess used a Poisson model for the number of accidents at a particular site, with a gamma prior on the mean rate  $m$  per unit time, of the form

$$f(m) = c^k m^{k-1} e^{-cm} / \Gamma(k).$$

If  $x$  accidents are observed in a unit of time at the blackspot and  $c$  and  $k$  are the prior parameters, the corresponding posterior parameters are  $c' = c+1$  and  $k' = k+x$ . A selection of prior parameters  $c$  and  $k$  can thus be interpreted as containing information roughly equivalent to having observed  $k$  accidents in  $c$  units of time prior to the sequence of accident data observed at the blackspot. Under the hypothesis of no effects due to treatments at the blackspots, the regression of  $m$  on  $x$  (the mean of the posterior distribution of  $m$ ) is  $\hat{m} = E(m|x) = (k+x)/(c+1)$ , which delineates the regression to mean effect:  $x > k/c$  if and only if  $\hat{m} < x$ .

A.G. Baker and D.R. Layne-Joynt (Unilever Research UK) discussed several applications of Bayesian methods; one especially interesting example concerned use of prior knowledge in analytical chemistry. When an analyst is asked to determine the constituents of a compound, he or she will often have some knowledge of the likely chemicals involved. Liquid chromatography was taken as an example. This method gives peaks of concentrations of chemicals emerging from the analytical column; the presence of a peak corresponding to some known chemical provides evidence in support of the presence of that chemical. In this case the chemist was asked to determine whether a chemical  $X$ , or a very similar chemical  $Y$ , was present in a compound. It was thought that it was more likely than not that  $X$  or  $Y$  was present and that either was equally possible. The chemist had some experience with the detection and false alarm rates in analyses for  $X$  and  $Y$ . This information was summarized as follows:

Compound	Prior	Class. X
X present	1/3	X:0.9
Y present	1/3	X:0.25
neither present	1/3	X:0.1

The analysis indicated that  $X$  was present and Bayes' formula then gave the posterior probability that  $X$  was present,  $P(X \text{ present} | X \text{ classified}) = 0.72$ . While there may be room for disagreement about the values assigned in the table above, the general idea is that preconceptions (prior knowledge) about the probable presence of  $X$  should be taken into account.

J.R. de Wit (Erasmus Univ., Rotterdam, The Netherlands) discussed an application of Bayesian methods to inventory reorder policies for slow-moving items (items having a mean demand not exceeding 10 per unit of time). He considered a continuous review  $(s, Q)$  system, in which the inventory level of the item is

monitored continuously with reorder of quantity  $Q$  whenever the level in the inventory drops below  $s+1$ . The methods suggested in the inventory literature for  $(s, Q)$  systems are not appropriate for slow-moving items, according to de Wit. Using a multinomial distribution for the size of a demand, together with a multidimensional beta prior on the multinomial parameter vector, he developed optimal integer values for  $s$  and  $Q$ , taking into account the posterior distribution of demand for the item. Whenever a demand occurs, appropriate adjustments are made to recompute the posterior distribution of demand, which is then used to derive new  $s$  and  $Q$  values for the next epoch. Thus an iterative solution is employed.

Perhaps the high point of the conference was a paper presented by A.F.M. Smith (Univ. of Nottingham), "The Monitoring of Kidney Transplant Patients." The particular problem studied was to develop an on-line statistical procedure for monitoring the progress of kidney function in individual patients who had recently received a transplant. The series of measurements made on the patients tends to be extremely noisy because of considerable biological variation and errors arising in the collection, measurement, and processing of the data. In addition, the series may be subject to several different types of abrupt change. Some of the changes will correspond to biological events of direct interest and importance, possibly calling for immediate clinical intervention. An example of this would be initial rejection by the patient of the transplanted kidney. It is therefore important to be able not only to detect changes in pattern, but also to distinguish between different forms of change, a feature that often precludes the use of simple monitoring techniques.

Smith has adopted the multiprocess Kalman filter, introduced by Harrison and Stevens, to model and analyze the measurements taken on the transplant patients. This, he said, provides a flexible, general framework within which to model noisy time series subject to abrupt changes of pattern. Smith illustrated his approach with a detailed case study carried out with the Renal Unit at the City Hospital, Nottingham.

It should be mentioned that a short address was delivered at the conference dinner by Sir Harold Jeffreys, who is a great pioneer in probability and statistics. The conference was highly successful and a large number of innovative and useful applications of Bayesian methods were presented. The Institute of Statisticians plans to publish proceedings of the conference.

D.R. Barr

ONR London

# STATISTICAL RESEARCH AT ROYAL HOLLOWAY COLLEGE

Although the statistics group at the Royal Holloway College in Egham, England, is small, the principal researchers in the group, Profs. Edward Godolphin, Brenton Clarke, and Peter Key, are interested in a wide range of estimation problems. The work of Godolphin and Key is generally related to time series applications, while Clark devotes most of his efforts to problems involving linear models and mixtures of distributions. In what follows, some examples of recent achievements are described, based on information the author received on a recent visit to the college.

The problem of estimating the parameters of a mixture of two normal distributions is old and well established in the statistical literature. For example, in 1894 Karl Pearson suggested moment method estimators as a means of addressing it. The simplest version of the problem is one in which a random sample is to be drawn on a random variable  $X$ , where  $X \sim N(\mu_1, \sigma_1^2)$  with probability  $\lambda$  and  $X \sim N(\mu_2, \sigma_2^2)$  with probability  $(1-\lambda)$ ; the goal is to estimate the five parameters  $\lambda, \mu_1, \mu_2, \sigma_1^2$  and  $\sigma_2^2$ . The long history of research efforts to obtain estimators for the parameters gives further evidence of the importance of the problem, which arises in a wide range of applications in engineering, biology, economics, and geology, and the difficulty of the solution. If it is known that  $\sigma_1^2 = k\sigma_2^2$  with  $k$  known, then maximum likelihood estimators are consistent and can be computed using straightforward numerical methods. However, if  $k$  is not known, the likelihood function is unbounded and any attempt to determine the location of a global maximum leads to inconsistent estimates. Further complicating the problem, no sufficient estimator exists for the parameters involved.

A number of estimation approaches have been suggested in addition to the method-of-moments approach mentioned above. They include estimates corresponding to a local maximum of the likelihood function in the interior of the parameter space (due to Kiefer), estimators based on the sample moment generating function (due to Quandt and Ramsey), and methods based on minimum distance (due to Brenton Clarke). Clarke has determined statistical properties of the estimators that minimize the mean squared error distance and has derived closed form expressions for the covariance matrix of the asymptotic normal distribution of the estimators.

Clarke uses the distance function

$$W_n^2(\theta) = \int_{-\infty}^{\infty} (F_n(x) - F_\theta(x))^2 dx,$$

where  $F_n$  is the empirical distribution function and  $F_\theta$  is the population CDF,

$$F_\theta(x) = \lambda \Phi\left(\frac{x - \mu_1}{\sigma_1}\right) + (1 - \lambda) \Phi\left(\frac{x - \mu_2}{\sigma_2}\right),$$

$\theta$  represents the parameter vector, and  $\Phi$  denotes the standard normal CDF. He has obtained closed form expressions for the estimators that minimize  $W_n^2(\theta)$  and has shown that  $\lambda$ , which is easy to compute, is unbiased and efficient. Through simulations, Clarke has obtained evidence that his estimators are robust, and he believes that they are generally better than the various available competitors for use in applications involving normal mixtures.

Godolphin and Key have been working on the structure of dynamic linear models for representing time series data. The models can be described as follows: Suppose  $\{Y_t; t=0, \pm 1, \dots\}$  denotes a sequence of observations generated by the model  $Y_t = F\theta_t + V_t$ , where the  $n$ -component system vector  $\theta_t$  in turn satisfies  $\theta_t = G\theta_{t-1} + W_t$ . Assume that the vector  $F$  and the matrix  $G$  are known and do not vary with time; moreover, assume the errors  $V_t$  and  $W_t$  have zero means and have known variance  $v = \text{var}(V_t)$  and covariance matrix  $w = E(W_t W_t')$ , respectively. Under various additional specifications the predictor  $y_t(k)$  of  $Y_{t+k}$  is of the form

$$y_t(k) = F G^k \hat{\theta}_t; \quad k=1, 2, \dots, (1)$$

where  $\hat{\theta}_t$  is a suitable estimate of the system vector  $\theta_t$ , based on the data available at time  $t$ . For example, if the errors  $V_t$  and  $W_t$  are independent and normal, then  $\hat{\theta}_t$  is determined by the Kalman updating formula

$$\hat{\theta}_t = G \hat{\theta}_{t-1} + A_t (y_t - F G \hat{\theta}_{t-1}) \quad (2)$$

where  $A_t$  is the Kalman gain vector. Godolphin and Key have shown that under what they call a minimal rank condition, the forecast given by equations (1) and (2) coincides in the steady state with that for a general autoregressive integrated moving average (ARIMA) model as defined by Box and Jenkins. The minimal rank condition is a condition on  $G$  that takes the place of the observability condition often imposed in control-theory treatments.

Godolphin has also been interested in Gaussian moving average processes, in particular estimation of parameters in models. Several authors have described methods for computing the maximum likelihood estimates, but generally they involve substantial computational complexity. Godolphin has developed an approximate method, based on solving equations that are asymptotically equivalent to the normal equations. The approach gives an expression for the estimator of each parameter as a linear combination of a suitably large set of sample serial correlations. The method does not depend on library subroutines such as fast

Fourier transforms, maximization procedures, or matrix inversion. It apparently has substantial computational advantages over the exact solution methods currently available, and it leads to essentially the same estimates for samples of sizes commonly encountered in practice. According to Godolphin, the results indicate that the additional effort required to compute exact maximum likelihood estimates is hard to justify. Moreover, he has some evidence that methods commonly used for maximizing the exact likelihood function are less stable than the approximate procedures he has devised.

In summary, the small group of statisticians at Royal Holloway College, under Godolphin's leadership, is active and productive. The work being done there with estimation, particularly for time series models, is of high quality and is of importance in a wide range of applications.

D.R. Barr

ONR London

## NEWS & NOTES

### NOVEL MICROSCOPE TENSOMETER DESIGNED AT UNIVERSITY OF BIRMINGHAM

A microscope tensometer designed at the University of Birmingham was recently developed at Loughborough Consultants Ltd. The tensometers allow specimens to be examined with either transmitted or reflected light microscopes while being strained. The tensometer is equipped to provide a continuous readout of stress and an output to an X-Y recorder. Bright-field, dark-field, phase-contrast, or polarized light microscopy can be used. Deformation or surface strain behavior can be aided by placing a reference grid on the specimen using standard experimental methods. A maximum specimen width of 3 cm can be used. Examples of use are for examining the failure mechanism of fiber composites, stress optical analysis on PVC sheet, heat seal failure examination, and measuring the growth rates of diamond cavities in polycarbonate sheets using the basic principles of fracture mechanics (see Walker, Haward and Hay, for example, *J. Mat. Sci.* 16 817-824 (1981)).

V.T. Stannett  
ONR LONDON

### PHD SUBMISSION RATES

The Science and Engineering Research Council (SERC) is one of five councils in the UK funded by the Department of Education and Science. Its primary purpose is "to sustain standards of education and research in the universities through the provision of grants and studentships and by the facilities which its own establishments provide for university research." The SERC recently published results of a survey relating to research students who received SERC awards in 1977. Institutions were asked to give information on the number of students who had formally submitted a thesis by October 1981 and the number of students still registered for a PhD as of October 1981. The results are tabulated by institution in Table 1 and by subject area in Table 2.

**Table 1 — PhD submission rates etc by**

#### institution

Universities	No of students registered	Number submitting by 1.10.81	No still registered at 1.10.81
Aston	84	35	24
Bath	33	12	13
Birmingham	73	40	25
Bradford	40	14	20
Bristol	60	31	27
Brunel	17	10	6
Cambridge	145	98	41
City	18	5	5
Cranfield Institute of Technology	14	4	7
Durham	33	16	15
East Anglia	24	11	12
Essex	13	4	3
Exeter	16	6	8
Hull	27	14	12
Keele	7	5	2
Kent	25	11	13
Lancaster	23	11	11
Leeds	85	34	39
Leicester	33	15	16
Liverpool	50	23	24
London:			
Bedford	12	5	5
Birkbeck	7	4	1
Chelsea	16	11	2
Imperial	124	73	34
Kings	35	15	16
Queen Elizabeth	17	4	11
Queen Mary	30	12	14
Royal Holloway	17	5	11
University	50	26	3
Westfield	11	4	5
Other institutions	20	9	8
Loughborough	32	9	19
Manchester	106	60	28
UMIST	47	14	15
Newcastle	56	27	19
Nottingham	62	42	13
Open	6	2	2
Oxford	140	90	35
Reading	35	11	16
Salford	25	17	1
Sheffield	57	24	31
Southampton	62	28	22
Surrey	28	12	10
Sussex	52	27	18
Warwick	40	15	16
York	25	11	12

	No of students registered	Number submitting by 1.10.81	No still registered at 1.10.81
University of Wales:			
Aberystwyth	24	11	9
Bangor	22	4	17
Cardiff	28	9	16
Swansea	27	9	14
UWIST	16	4	11
Welsh National School of Medicine	1	1	0
Aberdeen	20	9	7
Dundee	11	4	3
Edinburgh	50	26	17
Glasgow	46	33	7
Heriot-Watt	23	15	2
St Andrews	14	4	7
Stirling	15	4	9
Strathclyde	35	19	14
Ulster	1	0	1
Total Universities	2265	1108	824
Total Polytechnics*	94	23	50
Other Institutions*	12	5	3
Grand Total	2371	1136	877

\*The numbers of students at polytechnics and other institutions were generally too low to make individual detail meaningful

**Table 2 — PhD submission rates etc by SERC Board**

	No of students registered in 1977	Number submitting by 1.10.81	Still registered at 1.10.81
Science Board:	1378	733	478
Biological Sciences	520	258	187
Chemistry	507	318	145
Mathematics	149	80	46
Physics & Neutron Beam	202	77	100
Engineering Board	755	307	311
Astronomy, Space & Radio Board	74	37	27
Nuclear Physics Board	62	41	15
SERC/SSRC Committee	66	8	29
Other	36	10	17
Total	2371	1136	877

It should be noted that the SERC has stated that its awards are made to facilitate training in research, rather than being aimed at awards of degrees. Nevertheless, the number of students receiving SERC grants at the various universities, the differences in completion rates and withdrawal rates at the various institutions and in the various areas of study are interesting statistics.

*D.R. Barr*

ONR London

#### NO FOULING ON THE QE2

After her participation as a troop carrier in the Falklands war, the Queen Elizabeth II recently returned to Southampton drydock for renovation and reentry to the Atlantic cruise trade. In November 1980 the hull was coated with Intersmooth, a self-polishing copolymer antifouling paint. Inspection in the summer of

1982 reportedly found the ship to be almost totally free of fouling. A policy of annual inspection, fresh-water washing, and repainting of damaged areas seems to be an effective antifouling policy for the QEII.

*N.A. Bond, Jr.*

ONR London

#### CHALLENGER SOCIETY MEETING

The Challenger Society met at the Scientific Societies Lecture Theatre in London on 15 September 1982, to consider the topic "The design and operation of research ships" at the 284th scientific meeting.

The first part of the meeting considered requirements, design, and operation of research vessels. Dr. B.S. McCartney, Institute of Oceanographic Sciences, Wormley, gave a detailed and complete rundown of the various matters that need to be considered in ship design. He is particularly well informed on the subject, being in general charge of the design of a new research vessel, the *Charles Darwin*, which is planned to replace the *RSS Shackleton*. Preliminary plans for the new vessel were on display.

Captain G.H. Selby-Smith, of the Research Vessel Services, Barry, discussed "Marine Requirements" very much from the viewpoint of an experienced skipper, commenting particularly on hull form, propulsion systems, and wheel-house design. He concluded by commenting that what is needed is a good ship, good crew, and good weather. (RVS is an establishment of the Institute of Oceanographic Sciences that operates the institute's research fleet and maintains a pool of oceanographic equipment.)

The paper by C.M.G. Adams of RVS, Barry, had to be canceled and in its stead the secretary of the society, Prof. R.I. Currie, summarized the article by Dr. Wayne Burt on "Research Vessel Management in Europe" that appeared in ESN 36-8 (1982), and F.A. Richards commented briefly on the operation of the US research fleet, emphasizing primarily the development and operation of the UNOLS (University National Oceanographic Laboratory System) in scheduling the US academic fleet.

The afternoon session was devoted more to specifics. Mr. A.E. Fisher (IOS, Wormley) described entertainingly and in some detail experiences in mounting prolonged cruises of *RRS Discovery*. The cruises involved changes in equipment and scientific parties in far-away places, and many difficult and sometimes amusing problems have been encountered.

Dr. W. Zenk of the Institut für Meereskunde, Kiel, described two new German research vessels, the *Poseidon* (60 m) of the Institut and the *Gauss* (68 m) of the Deutsches Hydrographisches Institut, Hamburg. Dr. T.J.G. Francis (IOS, Wormley) discussed

experiences on the USNS Mizar of deploying oceanographic instruments through a center well.

Jonathan Leiby, marine architect from Woods Hole Oceanographic Institution, had been especially invited to consider guidelines for the future. In luncheon conversation he confided that the present is pretty uncertain, but we can hope for a more favorable climate for funding oceanographic research in the future.

*F.A. Richards*

ONR LONDON

#### HUMAN SENSITIVITY TO LOW-FREQUENCY SOUND

People who are bothered by low-frequency sound sources often have two problems: the usually continuous irritation from the sound itself and the disbelief of other people who cannot hear the signals and who think that the affected person is hearing things. A typical case was reported recently from the Water Board in the city of Bristol, England. A secretary reported that her IBM memory typewriter gave her severe headaches; she had to wear ear muffs at work in order to stay on the job. Tests showed that she could tell when the machine was turned on, even if she was in another room. After much medical and psychiatric consultation, an audiometric check showed that the woman simply had extraordinarily low subsonic thresholds. When her typewriter was taken out, her headaches ceased, but they started again when a new computer was installed in a nearby building. The secretary retired and then found that a new television set caused the headaches to recur; apparently a memory tuning device in the set was the cause.

The Institute for Sound and Vibration Research (Bristol, UK) has investigated several cases like the one above. Andrew Middleton of the Institute believes that many complaints about noise in large computer centers and offices may not be due to the electronics and VDU equipments themselves, but to the ventilating systems. According to him, low-frequency sound from fan motors may be inaudible in the open air but can resonate strongly at the same frequency in a building. A mysterious "Bristol hum", which was vaguely sensed by many people, was eventually found to be caused by a large factory fan. Low-frequency sound energy checks are not ordinarily included in health and safety surveys, but they might deserve consideration where there are large motors and mechanical equipment operating under possibly resonant conditions. Studies at NASA and elsewhere show that extremely powerful low-frequency pulses can have drastic effects on people; it is still an

open question whether moderate levels of stimulation can have discernible and cumulative effects.

*N.A. Bond, Jr.*

ONR LONDON

#### CADMIUM POISONING IN EUROPE

Like other heavy metals, cadmium can produce drastic effects when ingested into the human body. It often concentrates in the liver, and it can influence kidney function. One effect of cadmium poisoning is to deplete bones of calcium. Under extreme depletion, bones may break from light pressure, such as the weight of a blanket.

There have been famous instances of cadmium poisoning in Japan for some decades. More recently, elderly Belgians living near a cadmium smelter in Liege have shown symptoms. In 1979, the vegetable crop near Shipham, England, was under suspicion.

A new survey by the Monitoring and Assessment Research Centre, Chelsea College, University of London, contains further disquieting information. The report estimates that as many as 10% of Europeans may show kidney symptoms that are believed to be early signs of cadmium poisoning. The survey, authored by Malcolm Hutton, attributes much of the human cadmium intake to phosphate fertilizers and indicates that the cadmium from that source is probably greater than from the atmospheric inputs. If this is so, then cleaning up the atmospheric pollution from EEC iron and steel industries probably would not reduce cadmium poisoning significantly.

*N.A. Bond, Jr.*

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#### AVERSIVE CONDITIONING TO JUNK FOOD

Many overweight people seem to be addicted to foods such as candy bars, cookies, and glazed doughnuts. Some studies have shown that under laboratory conditions, aversive conditioning can be accomplished. For instance, the target food and images of eating it may be associated with electric shocks, emetics, or other noxious stimuli. Some subjects may then report aversion to the target item or even nausea at the mere thought of it. When tested for practical weight loss over a



period of months, however, such methods are unimpressive.

At the International Congress of Applied Psychology in Edinburgh last July, Edward Abramson and Drew Jones (California State University, Chico, US) reported on a simple conditioning procedure that seemed to be effective for at least a few days. The researchers did not take overall weight loss as the criterion, as they believed that obesity is not caused by the overconsumption of a few special foods. They argued that aversive conditioning could be best evaluated by means of changes in reaction to specific food items. The following program was adopted: (1) using the Strongsin-Hinsie-Peck salivation measure (three 2-minute collections); (2) assigning a palatability rating; and (3) keeping a diary record of target food consumed. There were three groups in the test: experimental, placebo, and control. For the experimental group, subjects were instructed to snap a rubber wrist band (6 mm x 180 mm) every time they thought of, craved, or came in contact with the target food. If they elected to eat it, then the directions were to snap the band with each bite. Placebo group members wore a bright hospital wrist band, but it could not be snapped. Controls were given no treatment, but were asked to record palatability ratings and to keep consumption diaries. Assignment to the 3 groups was stratified by percentage overweight with 14 people in each group. Measurements were made before the treatment and one week later.

The treatment group registered significant reductions in milligrams of target-food salivation (365 to 270), in palatability ratings (10 to 6.75), and in reported target-food consumption (6.7 items to 1.5 items). None of the placebo or control changes was significant.

Mild punishment seemed to be the key factor in the treatment, as the nonpunishing "reminder" hospital band for the placebos didn't produce behavioral change. Generalization took place, too, with some experimental subjects reporting that they had begun to associate negatively with ancillary stimuli such as junk food TV commercials and doughnut shops.

*N.A. Bond, Jr.*

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#### GENETICALLY LIGHT BEER

Ordinary beer can be fattening because of the dextrin carbohydrates in the beverage; these are not broken down by brewer's yeast. Geneticists at the Brewing Research Foundation (UK) have produced a hybrid brewer's yeast strain that has a dextrin-fermenting gene. As industrial brewer's yeasts ordinarily do not

mate, a special "rare mating" technique was employed; the yeasts were grown together in special cultures so that neither parent would grow, but any hybrid would grow even if only a few cells mated. The resulting hybrid destroyed dextrin, but it also gave an unpleasant flavor to the beer; the Brewing Research Foundation investigators were able to identify and eliminate the offending gene, so that low carbohydrate beer now tastes like the real thing.

In the US, brewers use normal yeast and add dextrin-consuming enzymes directly to the fermenting mix. Theoretically the genetic engineering approach should be a preferred solution, and brewers in many countries will undoubtedly be evaluating the new British yeast hybrids.

*N.A. Bond, Jr.*

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#### TRAINING CHAMPIONS AND PSYCHOLOGICAL LOAD

A training champion is someone who performs well in neutral practice situations but fails repeatedly in real competition. The sports world is full of such people as are the performing arts. In ordinary school examinations, there are also many students who do much worse on critical examinations than their actual knowledge would indicate. The common-sense explanation is that such people "...can't handle stress."

Standard psychological practice is to give tests when the subjects are well rested and in a relaxed frame of mind. Actually, according to results from G. Guttman and his colleagues in the Psychological Institute at the University of Vienna, it may be much better to test subjects under rather severe load, if the desired actual performances must be accomplished under real stress. The first validation of test loading was done with 33 rock climbers. Such scores as sensori-motor coordination and visual processing were only moderately correlated with actual performance on the rock face. When additional test load was imposed, however, the correlation between test score and climbing criterion improved markedly. The best test for predicting actual movement across the rock face was to have the subjects perform a pursuit rotor task with the dominant hand while pulling an expander with the other hand. By such measures, it appears that some subjects show an unchanged or increased score under load, whereas others deteriorate markedly; the "increasers" are apt to be the best performers in the real situation.

The Vienna investigators have extended their work into several domains such as parachuting, table-tennis competition, and judo wrestling. Results from the testing of 28 judo

practitioners were convincing; under no-secondary-load testing, the baseline visual processing scores of 14 top sportsmen were nearly identical to scores from 14 control judo athletes. A secondary task produced increased visual information processing in the real champions but decreases in the training champions.

The training champion phenomenon has not been fully analyzed. One conjecture relates to the approach-avoidance motivation with which the real stressful task is approached. In their rock-climbing and parachute samples, the Vienna psychologists found the successful people were those who had a higher approach motivation both before and after the critical event (rock climb or parachute jump). This leads to the possibility of using the rate of approach motivation buildup and dispersion as a predictor variable itself, and it also suggests possible therapies for the training champion who can't get it together in the real case.

*N.A. Bond, Jr.*

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#### PETS, SOCIABILITY, AND STRESS REDUCTION

Several years ago an American researcher reported that ownership of a pet animal was the factor most highly correlated with 1-year survival following a heart attack (apart from the degree of severity of the disease). The finding provoked considerable discussion; one possible explanation was that pets such as dogs were exercised by their owners and that exercise was correlated with survival. However, even for the owners of pets other than dogs the likelihood of survival was better, so the explanation can probably be best sought in such factors as stress reduction on the owner, or the value of pets in structuring and accomplishing a set routine of life, or a non-casual relationship between pet ownership and other factors.

According to P.R. Messent of the Waltham Animal Studies Centre, Leicestershire, England, both diastolic and systolic blood pressures are slightly but significantly reduced when a pet dog is present. Incidentally, the heart rate and blood pressure of the dogs themselves tend to fall when they are petted. Related studies at the University of Pennsylvania showed that watching tropical fish in an aquarium produces significant drops in blood pressure.

Pet animals can, of course, serve in many ways as social facilitators. Messent reports that in English homes for the elderly, subjects who were given a pet parakeet showed significantly better self esteem and general adjustment than a control group. At least one recent study has indicated that introducing just one cat mascot into a ward of elderly persons will lead to positive effects. Messent performed an unobtrusive observational study of adult walkers through Hyde Park in London. The

walkers went over the same route almost every day and sometimes were accompanied by their pets. Messent unobtrusively recorded such behaviors as the number of greetings and the amount of conversation that took place, whether other people looked at the dog or owner, and whether other people slowed or stopped when meeting the observed person. There were nearly three times as many conversations lasting over 1 minute if a dog was present than in the same-walk but no-dog condition, and in general the pet seemed to serve as a social catalyst.

There is another side to human-animal relations. Recent British studies indicate strong relations between animal abuse in childhood and later aggressive behavior. In one set of 16 complaints of cruelty against animals at a local London Animal Control Center, 14 of the local individuals mentioned had been known previously to the center for cruelty offenses. Cruelty patterns are persistent: a study of American male psychiatric patients showed that people who had histories of childhood animal abuse were also more likely to exhibit assaultive behavior as adults, and to have experienced parental abuse or neglect. The literature on human-pet relations is now reaching the stage where much controlled research is being done. In October 1982, a major conference on the psychology of pet ownership is scheduled in London. The meeting is sponsored by the Society for Companion Animal Studies, and papers from the veterinary, medical, psychological, and institutional communities will be presented.

*N.A. Bond, Jr.*

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#### OBITUARY

Dr. Arthur H. Waynick, retired head of the Electrical Engineering Department and director and founder of the Ionospheric Research Laboratory at Pennsylvania State University, died August 31 while visiting England. Dr. Waynick served as a liaison scientist at ONR London in 1972-73. Condolences are extended to his wife, Lillian, and to their children, Thomas, Jon, and Devon. Dr. Waynick received many awards and honors, including the Navy Ordnance Development Award (1945), the Office of Scientific Research and Development Award (1945), and the Electronics Award of the American Institute of Electrical Engineering (1950-51).

EUROPEAN VISITORS TO THE US SUPPORTED BY ONR LONDON

<u>Visitor</u>	<u>Affiliation</u>	<u>Navy Lab./Org. to be Visited</u>
Dr. T.W. Choularton	Dept. Pure And Applied Physics Manchester, UK	NPCS (10 September 1982) NAVENVPREDRESFAC (10 September 1982)
Dr. Alon Gany	Technion, Haifa, Israel	NWC, China Lake. (15 September 1982) NPS, Monterey (17 September 1982)
Dr. T.E.R. Jones	Plymouth Polytechnic Plymouth, Devon, UK	Inst of Polymer Science, U. Akron (15 or 16 Sept 1982) ONR (17 September 1982)
Dr. G. Ottaviani	Physics Institute Modena, Italy	NRL (15 November 1982)

ONR CONSPONSORED CONFERENCES

ONR London can nonimate two registration-free participants in the conferences it supports. Readers who are interested in such participation should contact the Chief Scientist, ONR London, as soon as possible.

4th Europhysical Topical Conference on Lattice Defects in Ionic Crystals, Dublin, Ireland, 30 August - 3 September 1982.

MOLEC IV - European Study Conference on Low Energy Collisions, "Het Vennenbos," Eindhoven, Netherlands, 6-10 September 1982.

2nd International Workshop on "Ion Formation from Organic Solids II," Münster, Germany, 7-10 September 1982.

4th International Symposium on Gas Flow and Chemical Lasers, Stresa, Italy, 13-17 September 1982.

14th Europhysics Conference on Macromolecular Physics, "Polymer Crystals: Structure & Morphology," Vilafranca del Penedes, Spain, 21-24 September 1982.